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# PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



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Although no manuscript will be rejected merely because it does not conform to the style of PACIFIC SCIENCE, it is suggested that authors follow the style recommended herein and exemplified in the journal.

(Continued on inside back cover)



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## The Use of Pandanus Fruit As Food in Micronesia<sup>1</sup>

CAREY D. MILLER, MARY MURAI, and FLORENCE PEN<sup>2</sup>

THE PANDANUS, sometimes called screw pine, is widely distributed in Southeast Asia and all the tropical Pacific islands, but according to Dr. Harold St. John, Professor of Botany at the University of Hawaii, it is only in Kapingamarangi and the Marshall, Gilbert, and Ellice Islands that one finds the varieties with choice edible fruit. On the small and relatively dry low islands or atolls, pandanus and coconuts are the principal and sometimes the only vegetable foods.

Almost all parts of the pandanus plant are used by the inhabitants of these islands, the

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This work has been a joint project of, and financially supported by, three agencies:

The Pacific Science Board of the National Research Council provided a fellowship under which Mary Murai did the field work and made some of the analyses.

The United States Department of Agriculture, through a contract sponsored by the Human Nutrition Research Branch, Agricultural Research Service, provided the funds for most of the food analyses, which were made by Florence Pen.

The Foods and Nutrition Department of the University of Hawaii Agricultural Experiment Station furnished the laboratory, the equipment, and the necessary overhead, as well as the financial cost of the supervision for the analyses of the foods and the preparation of the manuscript by Carey D. Miller.

Pandanus was only one of the foods studied under this project. The complete publication will appear elsewhere.

<sup>2</sup> Department of Foods and Nutrition, University of Hawaii Agricultural Experiment Station. Manuscript received August 26, 1954.

leaves provide material for clothing and shelter, and for household use such as baskets and mats. The chief edible part is the fruit, especially the fleshy base of the keys.

There are two distinct sexes of trees for all varieties, male (staminate) and female (pistillate). The pistillate trees bear fruits of different sizes, varying from the inedible ones 3 or 4 inches in diameter, which weigh a pound or less, to the very large edible fruits weighing 20 to 30 pounds (see Fig. 1). A 30-pound fruit has approximately 50 keys and a core and stem weighing about 2 pounds.

Each fruit is made up of many small sections called keys (botanically a phalange), because though irregular in shape, they fit closely together to form a solid fruit. In a large fruit the keys are 3 to 4 inches long; at the outer end they are 1½ to 2 inches in diameter and at the inner end near the core ¾ to 1 inch (see Fig. 2). The rough outer surface may be green or yellow when ripe, but the inner edible end is always yellow-orange in color. The inedible varieties have fruits which, though smaller, look just like the edible types, but they are extremely astringent and bitter.

The chemical analyses and studies of the nutritive values of pandanus fruit reported in this paper were made on fruits from Micronesia: Majuro and Mille Atolls of the Marshall Islands and Kapingamarangi of the Caroline Islands.

## USE AS FOOD

The earliest account of the edible pandanus fruit and its use by the natives of the Marshall Islands is by Kotzebue (1821, 2: 8) who early in 1816, when he first touched at the Radak Island chain, observed "they had nothing with them except a few grains of pandanus, which they constantly chewed."

Kotzebue and Chamisso, the naturalist who accompanied the expedition, tell of being served "pandanus juice" which was pressed from the keys after they were bruised with a stone and which Kotzebue states, "had a sweet and spicy taste" (1821, 2: 10).

Discussing the abundant pandanus, Chamisso stated: "It is also diligently cultivated; numerous varieties, with improved fruits, which are to be ascribed to cultivation, are propagated by layers" (Kotzebue, 1821, 3: 150).



FIG. 1. Pandanus Fruit—Joibeb. From Ebon, Marshall Islands; weight  $19\frac{1}{4}$  pounds.

Kotzebue (1821, 2: 75) opined that "the pandanus contains very little nourishment," but noted that the natives "enjoy extraordinary health, and attain to an advanced and cheerful old age." His picture of the teeth, however, is quite in contrast to that of some of the early voyagers who remarked on the fine teeth of the Polynesians (Cook, 1784, 1: 380; King, 1784, 3: 125; Ellis, 1832-36, 1: 81). Kotzebue states: "All the islanders are

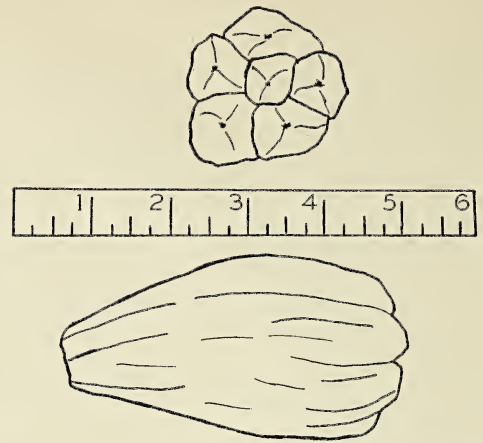


FIG. 2. A single key from a large Lojekerer, side and end views. Sketch by M. Higa.

great lovers of sweet things; and their chief food, which they draw from the sweet pandanus fruit, is probably the reason, that even children of 10 years old have not good teeth, and that they have generally lost them all in the prime of life" (1821, 2: 17).

Chamisso (Kotzebue, 1821, 3: 150) gives a rather detailed account of the making of pandanus paste (*mōkan*), which is essentially the same method used today. He also observed that the paste was "carefully preserved as a valuable stock for long voyages."

Pandanus has apparently always been an important food in the Marshall as well as the Gilbert Islands as it figures prominently in their folklore and is commonly considered to have come with their creation (Grimble, 1933-34, 54: 85, 97; James Milne, personal communication).

Selection and propagation must have been practiced by these isolated people for many years in order to have developed the fine edible varieties which are limited in their distribution.

No edible pandanus was in evidence when the dietary study was made in the Caroline Islands (Murai, 1954), but it was thought that it might have been out of season. Chamisso (Kotzebue, 1821, 3: 184) states that at the time of their visit (1817) that although



the pandanus grows on all the islands, "the fruit is neither eaten, nor ever used for an ornament. None of the improved kinds are found there."

In the Marshall Islands, each household owns some pandanus trees which may be near the house or at some distance from the dwelling. When ripe and ready for use, the large fruits are cut from the tree with a bush knife and the keys broken apart to be eaten raw or cooked.

Pandanus was in season in the Marshall Islands from January to the end of May, 1951, and at the time the dietary study was made in April both pandanus and breadfruit were being used (Murai, 1954: 14). On the low islands, pandanus is one of the important foods between breadfruit seasons, and, when breadfruit is abundant, pandanus may or may not be used.

The most common method of eating pandanus is to gnaw at the soft inner ends, leaving the long tough fibers attached to the keys. Children and adults seem to chew the keys almost continuously during their waking hours. People eat them much as Westerners might eat nuts or candy or smoke cigarettes. Chewing pandanus keys, talking and gossiping are an important part of their social life. Records of the amounts eaten and the nutrients furnished are given in the section on Composition and Nutritive Value.

The hard portion of the keys is used as fuel. The inedible ends also contain the seeds which can be removed only with great difficulty because they are enclosed in an unusually tough woody case and people rarely bother to extract them, although they are sometimes eaten.

In the raw state, the edible portion of the pandanus is merely a juice pressed from the cells embedded in coarse fibers. It is not a pulp but a liquid which when extracted in the laboratory has a small portion of solid material that settles to the bottom of a beaker. The juice is sweet and subacid with a pungent aromatic flavor. When cooked the starch

causes the juice to thicken and the edible portion becomes a soft pulp, resembling mashed sweet potatoes both in color and in texture. The flavor is similar to the raw juice.

If a good supply of other foods is available, the pandanus keys are more likely to be eaten in the raw state because people simply do not bother to cook them. But when the pandanus constitutes a large proportion of the diet (such as was observed in February, 1951, at Mejit Island, Mejit Atoll; Utirik Island, Utirik Atoll; and Ailuk Island, Ailuk Atoll; in the drier northern Marshall Islands), it is eaten cooked as well as raw, probably to add variety. It is also combined with other foods as listed below.

A glossary of the names of edible pandanus fruit, and products made from it, which were observed by one of us (M.M.) in the Marshall Islands in 1951 is as follows:

- Bop—The pandanus tree or the whole fruit made up of many keys.
- Kōbeo—Raw pandanus fruit.
- Eroum—Boiled or baked pandanus.
- Joanrong—Pandanus juice.
- Mōkan—Cooked and preserved pandanus pulp (see below for preparation).
- Beru—Soft pulp from boiled pandanus cooked with arrowroot flour to produce a sweet dessert.
- Mokanrul—Pulp of cooked pandanus fruit mixed with grated coconut and baked.
- Jakaka—Shredded fresh (uncooked) pandanus which is dried for almost one week and used as a confection.

The native people in most of the islands still make all the products from pandanus which their ancestors made. But where western influence is strong, or where more favorable conditions permit growing a greater variety of foods, they no longer preserve the pandanus, though they continue to enjoy it in the raw or freshly cooked state. Two products which we analyzed, that can be stored and used for emergency or as wanted, pandanus paste and pandanus flour, are described below.

### *Pandanus Paste (Mōkan)*

Wherever the pandanus constituted an important native food in the fresh and cooked state pandanus paste was also made, and is still made in some areas.

Many reports of scientists in the 19th and 20th centuries tell of the preparation of pandanus paste which they also refer to as pandanus conserve or preserve (Kotzebue, 1821, 3: 150; Finsch, 1893: 142; Kramer, 1906: 427; Kurze, 1887; Wendler, 1911: 271).

Details of the process may vary slightly in different localities but in general the paste is made as follows: The separated pandanus keys are cooked in a deep earth oven with alternating layers of fruit and leaves for as long as 2 days, though one report states for 12 hours (Wendler, 1911: 271).

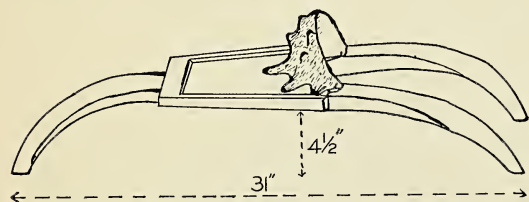


FIG. 3. Beka of traditional Marshallese type from Arno Atoll, Marshall Islands, collected in 1950 by Dr. Leonard Mason. Sketch by F. Pen.

The soft ends of the keys are rubbed against a scraper (formerly of shell, Fig. 3, but now more likely of metal) and the orange pulp is collected and dried on leaves. When it becomes a sticky mass, it is dried further over hot stones until it is thick and rather firm. The flat cakes are then rolled or pressed into a firm mass, wrapped in plaited pandanus leaves and firmly tied with coconut cord as shown in Figure 4.

These rolls are reported to have been of enormous size formerly—6 feet long and more than 1 foot in diameter (Finsch, 1893: 142; Kurze, 1887; Wendler, 1911: 271). Today they are more likely to be 12 to 15 inches long and 3 or 4 inches in diameter (Fig. 4). The model shown in Figure 5 is only 8 inches long.

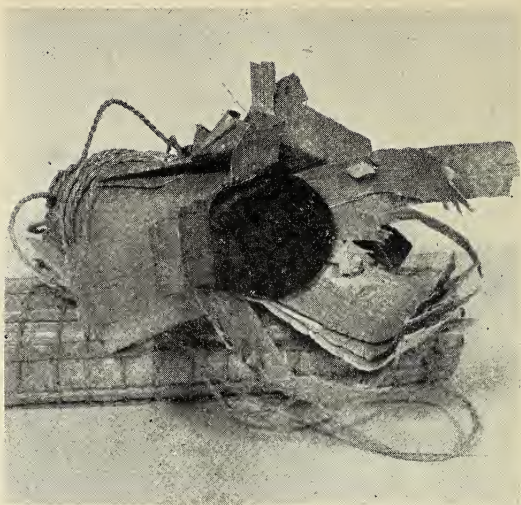


FIG. 4. Roll of pandanus paste in lauhala wrappings, collected at Mille Atoll by Dr. Kenneth P. Emory.

One account of the preparation of pandanus paste (Wendler, 1911: 272) calls attention to the unsanitary methods employed in making it, but probably they were no less sanitary than the handling of other foods.

The product is brown in color and tastes much like date or fig paste. It will keep a year or more and was formerly an important manner of preparing food for use on voyages and for storage in case of famine as well as for a regular food supply when the pandanus was not in season (see p. 4).

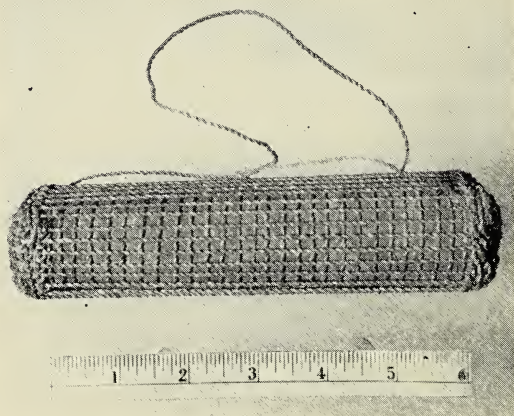


FIG. 5. Model roll of pandanus paste, collected at Majuro Atoll, by M. Murai.



*Pandanus Flour*

Although the accounts of anthropologists (Buck, 1950: 29; Grimble, 1933-34: 36) vary somewhat as to the method of making the dried product, referred to as "pandanus flour," they agree on the essential points which are here summarized.

The soft ends of the keys are cut off, placed in some type of coconut basket and cooked, usually by steaming in an earth oven until tender, about 1 hour. The cooked fruits are pounded to a paste which is made into large thick flat cakes, about 14 inches in diameter, which are dried (Buck, 1950: 29). In some places they are dried in the sun and finished over a grill of hot stones, and in other places they are dried over the hot stones first and then placed in the sun. The sun drying may take several days. They are usually given a final drying over hot stones and then the large crisp cakes are broken and pounded to a coarse flour-like consistency.

The product is dull yellow with a pleasant pungent odor. It can be stored in tubular containers made of plaited pandanus leaves and will keep for several years.

Grimble (1933-34: 39) reports that formerly pandanus flour and water were often the only food and drink taken on long voyages. The powder was simply mixed with water and drunk.

Dr. Katharine Luomala of the Department of Anthropology, University of Hawaii, who made observations in the Gilbert Islands in the latter half of 1948, especially on the Island of Tabiteuea, says that she saw both pandanus flour and pandanus paste being made (personal communication).

To our knowledge the pandanus is not made into a flour in the Marshall Islands as it is in the Gilberts and in Kapingamarangi.

## SAMPLES ANALYZED

The number of edible varieties of Pandanus in the Marshalls is uncertain, but St. John states that he has collected several score (personal communication).

One of us (M.M.), collected what were believed to be two native varieties of edible pandanus for chemical analyses, but St. John, who has examined the keys, believes them to be the same botanical species.

LOJEKERER (local name), *Pandanus pulposus* Martelli: This variety is the most common and widely distributed in the Radak chain. Four fruits on Majuro Island in April and May, 1951, had the following weights: 23, 32, 25, and 30 pounds. The keys are large, 3 to 4 inches long, 1½ to 2 inches in diameter, and weigh from about 3 to 7 ounces (100 to 200 grams) (Fig. 2). They are eaten both raw and cooked.

According to our informants this variety usually fruits but once a year. Our samples were obtained toward the end of the fruiting season.

JOIBEB (local name), *Pandanus pulposus* Martelli: This variety, which according to our informants, is also widely distributed, was thought to have originated on Jaluit of the Ralik chain. Four fruits on Majuro Island in April and May, 1951, had the following weights: 24, 30, 20, and 25 pounds. These fruits also had large keys.

We were informed that on Jaluit and Ebon, this variety usually fruits twice a year.

Under Composition and Nutritive Value, for clarity, we refer to the fresh pandanus by the two local names as if they were two horticultural varieties.

*Sample 1. Pandanus, Fresh*

1. Marshallese name—Lojekerer. *Pandanus pulposus* Martelli.
2. Date and place of collection: May 20, 1951. Uliga Island, Majuro Atoll.
3. Date vitamin assays begun: October 11, 1951. (Other analyses were made at a later date with repetition of moisture content to determine if there had been any loss as a result of freezer-storage.)



4. Preparation of sample after collection: Keys from three fruits, each from a different tree, were weighed, wrapped in groups of three in several thicknesses of wax paper, labeled, and placed in the freezer.
5. Transportation and storage: Frozen at 0° F. and held in Navy cold storage for 8 days. Kept frozen at 12° F. on a Navy vessel for 9 days enroute to Honolulu. Transferred to Foods and Nutrition Department, University of Hawaii Agricultural Experiment Station. The samples were examined and rewrapped in the same wax papers with an outer wrapping of aluminum foil. The keys were kept in freezer-storage at 0° to -5° F. until analyses were made.
6. Preparation for analyses: Samples were thawed in the refrigerator and then brought to room temperature. Total weights of keys and weights of edible portions were recorded. Edible portions were cut into small pieces and blended in the Waring Blendor without addition of liquid. The coarser fibers were removed by putting slurry through two thicknesses of cheesecloth to obtain a value more representative of the portion actually eaten. The juice so extracted was put into brown glass bottles filled with carbon dioxide, closed tightly with bakelite tops, labeled and held at 0° F. until all analyses had been made. Refuse, 59 per cent.

*Method of Crude Fiber Analyses:* To remove a large portion of the sugars from the pandanus samples to be analyzed for crude fiber, the samples were weighed, transferred quantitatively to filter paper in funnels, and extracted with distilled water in the refrigerator for almost 2 weeks. (Refrigeration was necessary to prevent the growth of molds.) The water extracted residues were dried on the filter papers for 48 hours, below 70° C., and then extracted with ether in the usual manner. The ether extracted residues and the attached filter paper were used for the crude fiber determinations. A blank of filter paper was

run simultaneously with each of the triplicate determinations of fiber.

*Sample 2, Pandanus, Boiled*

- 1, 2, and 3 same as sample 1.
4. Preparation of sample after collection: Keys from the same fruit as sample 1 were boiled without a cover in a large glass beaker of plain water for 30 minutes. The water was drained off and the keys cooled. Keys were weighed and labeled as stated for sample 1.
5. Transportation and storage: Same as sample 1.
6. Preparation for analyses: Same as sample 1, except that in addition to cutting off the soft ends, any soft juicy pulp remaining in the fibers was scraped out with a dull knife and added to the soft ends before mixing in the Waring Blendor. Refuse, 65 per cent.

*Sample 3, Pandanus, Fresh*

1. Marshallese name—Joibeb. *Pandanus pulposus* Martelli.
2. Date and place of collection: May 15, 1951. Majuro Island, Majuro Atoll.
3. Date vitamin assays begun: October 11, 1951. Other analyses same as sample 1.
4. Preparation of sample after collection: Keys from three fruits from three different trees, prepared in the same manner as sample 1.
5. Transportation and storage: Same as sample 1, but product held in Navy cold storage for 13 days before shipping.
6. Preparation for analyses: Same as sample 1. Refuse, 66 per cent.

*Sample 4, Pandanus, Boiled*

- 1, 2, and 3 same as sample 3.
4. Preparation of sample after collection: Keys from same three fruits as sample 3 were boiled in plain water in a large glass beaker for 30 minutes without a cover. After cooling, the soft end of the keys was

scraped with a dull knife to remove the pulp that constitutes the edible portion. The following were mixed in a Waring Blendor: 164 grams of pulp, 90 milliliters of 1 per cent oxalic acid, and shortly before slurry was completely blended, 5 milliliters of chloroform and 3 drops of mixed tocopherols were added. The samples were transferred to brown glass bottles, the plastic caps screwed down tightly and sealed with paraffin wax. Refuse, 75 per cent.

5. Transportation and storage: Bottles were kept at 36° F. at Uliga, Marshall Islands, until shipped by plane on May 29, 1951. The bottles were packed in cartons and shipped by air without refrigeration. The flight took 2 hours to Kwajalein, bottles were refrigerated at 36° F. in a Navy reefer during a stopover of 20 hours at Kwajalein. The flight from Kwajalein to Honolulu took 9 hours during which time they were not refrigerated. Samples were transferred to the Foods and Nutrition Laboratory and kept at 36° F. until analyzed.

#### *Sample 5, Pandanus Paste*

1. Marshallese name—Mōkan.
2. Date and place of collection: Summer of 1949. Mille Atoll, Marshall Islands, by Dr. Emory.
3. Date vitamin assays begun: October 10, 1949, except carotene which was determined in January, 1951.
4. Preparation: Similar to method described on page 6, but exact times of cooking and drying are not known. Thin slices were made into a roll approximately 3 inches in diameter and 14 inches long, covered with plaited pandanus, and tied securely with sennet (see Fig. 4).
5. Transportation and storage: Transported by ship without refrigeration to Honolulu. Brought to the Foods and Nutrition Department in September, 1949. Kept at room

temperature until analyses were begun, samples were removed from wrappings and thereafter kept refrigerated in tightly closed bottles.

#### *Sample 6, Pandanus Flour*

1. Polynesian name: paku harahara.
2. Date and place of collection: July, 1947. Kapingamarangi Island, by Dr. Emory.
3. Date vitamin assays begun: Vitamin A feeding tests, July, 1948; other vitamins, August, 1948.
4. Preparation: Similar to method described on page 7.
5. Transportation: Transported by ship without refrigeration to Honolulu. Delivered to the Foods and Nutrition Department in September, 1947.
6. Storage: Stored in tightly closed bottles in the refrigerator until analyzed.

#### ANALYTICAL METHODS

The thiamine, riboflavin, and reduced ascorbic acid of pandanus fruits were assayed chemically and niacin was determined microbiologically by the methods outlined by the Association of Vitamin Chemists (1951). The carotene content was measured physically by the chromatographic method of the Association, except that the extraction procedure was facilitated by using a mixture of solvents (petroleum ether, acetone, and alcoholic KOH) in the Waring Blendor, followed by centrifugation.

The analytical methods used for moisture, fat, crude fiber, total ash, and phosphorus were essentially those recommended by the Association of Official Agricultural Chemists (1950). (Details of all methods used and modifications of A.O.A.C. methods are on file in this laboratory and will be furnished upon request.) Protein was determined by the Winkler boric acid modifications of the Kjeldahl method (Markley and Hann, 1925).

A modification of the McCrudden method for calcium as recommended by the Human



TABLE 1  
COMPOSITION OF PANDANUS FRUIT  
(100 grams, Edible portion)

SAMPLE	WATER	FOOD ENERGY CALORIES*	PROTEIN	FAT	CARBOHYDRATES		ASH	CALCIUM	PHOS- PHORUS	IRON
					TOTAL	FIBER				
	gm.		gm.	gm.	gm.	gm.	gm.	gm.	mg.	mg.
1 Lojekerer, fresh.....	80.20	71	0.37	0.27	18.63	0.28	0.53	9.6	25.9	0.89
2 Lojekerer, boiled.....	83.74	58	0.22	0.20	15.42	0.08	0.42	13.3	19.6	0.39
3 Joibeb, fresh.....	84.17	56	0.38	0.27	14.55	0.30	0.63	16.4	33.0	0.58
5 Pandanus paste.....	17.83	293	2.23	1.38	76.14	3.28	2.42	134.4	108.2	5.74
6 Pandanus flour.....	10.80	196	2.94	1.25	80.71	14.95	4.30	797.0	114.0	1.73

\* Calories, with the exception of those in pandanus flour, were calculated by physiological energy factors recommended for fruit by the U.S.D.A. (Leung, Pecot, and Watt, 1952: 4). For pandanus flour, factors of 1.58, 8.37, and 2.24, respectively, were used for protein, fat, and total carbohydrate by difference. These factors, based on the heat of combustion values for fruit and the digestibility coefficients for wheat bran, were tentatively recommended for use in calculating the calories in pandanus flour by the Human Nutrition Research Branch, Agricultural Research Service (personal communication).

Nutrition Research Branch, Agricultural Research Service, United States Department of Agriculture, was used (personal communication).

Iron was estimated by the Saywell and Cunningham (1937) o-phenanthroline colorimetric method taking all possible precautions in the laboratory to prevent contamination with iron.

COMPOSITION AND NUTRITIVE VALUE

The pandanus products analyzed were: two varieties of fresh and cooked pandanus from the Marshall Islands (Majuro) collected in 1951, one sample of pandanus paste collected in 1949 by Dr. Emory at Mille Atoll, Marshall Islands, and one sample of pandanus flour from Kapingamarangi, also collected by Emory in 1947. The data on composition are summarized in Tables 1 and 2.

*Fresh, Raw, and Cooked Pandanus Fruit*

The fresh fruit contains but small amounts of protein and fat (less than 0.5 per cent), consequently its greatest food value may be ascribed to its carbohydrate, mineral, and vitamin contents.

The carbohydrate content (14 to 18 per cent) of the edible portion of the fresh pandanus is a little less than raw potatoes, somewhat greater than fresh fruits such as apricots and peaches, and about the same as apples and pears (Watt and Merrill, 1950). The moisture content of 80 to 84 per cent is also similar to these fruits. The edible portion of the fresh, raw pandanus fruit is juicy, whereas the cooked product has much the consistency of a moist, cooked, mashed sweet potato. The fresh samples of Lojekerer and Joibeb were examined and found to contain starch granules which were ruptured in the cooked product and which were easily stained blue with iodine. The starch granules of both varieties were round and relatively small, averaging 9 microns for the Lojekerer variety and 6 microns for Joibeb. The raw juice of the Joibeb

which we examined, obviously contained more starch than the Lojekerer and it also thickened to a greater degree when small samples of the extracted juice were cooked in the laboratory. Whether or not this difference may be explained on the basis of ripeness of the two samples or as a true varietal characteristic, can be determined only by additional tests. The thickening which takes place on cooking can be explained by the presence of the starch grains, but pectins, for which no tests were made, may also be present.

Pandanus fruit contains more calcium than do such temperate climate fruits as apples and peaches, and one sample had as much calcium as fresh apricots and almost as much as orange juice. Our fresh samples of pandanus were equal to or better than white potatoes as a source of calcium but they contained only about half as much calcium as average sweet potatoes. No determinations for oxalates were made and only digestion studies would determine whether or not the calcium is well utilized.

The phosphorus content of pandanus is about the same as that of the fresh fruits listed above but is much less than that of potatoes and sweet potatoes.

The iron content of our fresh samples varied but compares favorably with the fresh temperate climate fruits already mentioned and with potatoes and sweet potatoes.

Pandanus is a good source of provitamin A, the Lojekerer variety being superior to yellow peaches, but not so good as apricots or yellow sweet potatoes. Since the Marshallese, as well as some other island people (Murai, 1954: 14, 186; Spoehr, 1949: 153; Luomala, 1953: 15) consume little if any green and yellow fruits and vegetables, pandanus may constitute the most valuable source of provitamin A in their diet.

Pandanus is at least as good a source of thiamine, riboflavin, and niacin as are apples, peaches, apricots, and pears. It is a less good source of thiamine and riboflavin than potatoes and sweet potatoes. However, there may have been some loss during the period of transportation and storage prior to analysis. Pandanus contains less niacin than white potatoes but more than sweet potatoes, apples, and pears and about the same amount as apricots and peaches.

Both samples of the Joibeb contained approximately twice as much thiamine as the Lojekerer, but the differences in riboflavin and niacin content of the two varieties were small and not consistent for the samples analyzed.

The ascorbic acid content of the boiled sample of pandanus is about four times as great as that of the two fresh samples (Table 2). Possibly inactivation of the enzymes in the cooked sample prior to the long period of transportation and storage may account for

TABLE 2  
VITAMIN CONTENT AND pH OF PANDANUS FRUIT  
(100 grams, edible portion)

SAMPLE	CAROTENE*	THIAMINE	RIBOFLAVIN	NIACIN	ASCORBIC ACID	pH
	mcg.	mg.	mg.	mg.	mg.	
1 Lojekerer, fresh.....	1242	0.031	0.038	0.88	2.3	5.2
2 Lojekerer, boiled.....	847	0.024	0.034	0.71	8.9	5.1
3 Joibeb, fresh.....	184	0.052	0.025	0.95	2.6	4.9
4 Joibeb, boiled.....	291	0.059	0.042	0.73		
5 Pandanus paste.....	1078	0.037	0.062	2.47	(1.5)	5.6
6 Pandanus flour.....	1200 I.U.†	0.062	0.156	2.25		5.8

\* Total carotenes; chromatographic method.  
† Biological determination of vitamin A value with rats.



this. Obviously additional studies are needed to determine the range and typical ascorbic acid values for this fruit.

To determine what proportion of the pandanus keys are usually eaten, 50 children at the Marshall Christian Training School at Ronron cooperated in a simple experiment. A single raw key was given to each student and his name and the weight of the key were recorded. They were asked to eat the pandanus in the usual way and the remaining inedible portion was again weighed.

The weights of single keys ranged from 130 to 200 grams, with an average of 156 grams. The weight of the edible portion ranged from 40 to 102 grams (mostly 60 to 90 grams), with an average of 75 grams. This figure for the weight of the edible portion of a single key has been used for all calculations in Table 3.

TABLE 3  
NUTRITIVE VALUE OF THE EDIBLE PORTION  
OF PANDANUS KEYS

NUTRIENTS	1 KEY 75 GMS.	20 KEYS 1500 GMS.
Calories.....	53	1060
Protein gm.....	.28	5.6
Fat gm.....	.20	4.0
Calcium mg.....	7.2	144
Phosphorus mg.....	19.4	388
Iron mg.....	.7	14
Carotene mcg.....	932	18,640
Thiamine mg.....	.02	.4
Riboflavin mg.....	.03	.6
Niacin mg.....	.7	14
Ascorbic acid mg.....	2	40

While this little study indicates that almost 50 per cent of the key is edible, when the keys were prepared for analyses in the laboratory, the waste was much greater and the edible portion was found to range from 25 to 40 per cent. The edible portion of the cooked product was somewhat greater than the raw. It is probably easier to suck or gnaw out the sweet juice or pulp than to obtain it by mechanical means, and the size and ripe-

ness of the fruit, as well as variety, may influence the proportion of waste.

The dietary study in the Marshall Islands (Murai, 1954) included weekly records of 324 people 1 year of age and over; of this number, 138 ate pandanus, some for only 1 day, others for 6 days out of 7, making a total of 293 days on which pandanus was recorded. The number of large keys consumed ranged from 1 to 25 for all ages. Many ate at least 10 keys and several ate 20, the highest recorded was 25. Children 1 year old ate as many as 10. Records for 18 different days for nine children, 2 and 3 years old, showed that they ate 2 to 10 keys with an average of 5 keys per day.

The nutrients obtainable from one and from 20 keys have been calculated on the basis of our figures for raw Lojekerer and are summarized in Table 3. The conservative value of 3 milligrams of ascorbic acid per 100 grams of edible portion has been used for the calculations in this table although it is highly probable that the value is greater when the pandanus is eaten fresh.

An estimate of the nutritive value of the fresh pandanus may be made by evaluating the contributions to the diet made by 20 keys, which is not at all an unusual quantity, even when a variety of other foods is available. Twenty keys would supply about half the calories needed per day by a small and not very active person, all of the provitamin A, niacin, and iron, about one-third the thiamine, almost half the riboflavin, and more than half the ascorbic acid, judging from the National Research Council's standards or "Recommended Daily Allowances" for all nutrients except calories which are in excess of what the island people would require (Food and Nutrition Board, 1953: 3). Twenty keys would provide little protein, calcium, or fat but would make a good contribution toward the phosphorus needs.

On the basis of our analyses, it is obvious that the greatest contributions of pandanus fruit to the diet are calories, provitamin A, and ascorbic acid. When large amounts are



eaten, the quantities of the three minerals (Ca, P, and Fe) obtained are not inconsiderable but the variety (or varieties) which we analyzed indicate that the edible portion is not an important source of calcium and phosphorus.

It should be emphasized that the groups studied on Uliga Island and Majuro Island, Majuro Atoll, had a rather varied diet and a number of other foods, but in the isolated islets where pandanus, coconut, and fish are often all that is available, half or more of the caloric needs are probably satisfied by pandanus. Coconuts would supply the fat needed and fish and shellfish would furnish not only protein but calcium and phosphorus, especially when small fish are eaten whole.

If the value of about 8 milligrams of ascorbic acid obtained for the cooked sample should prove to be typical of all fresh pandanus, then the fruit would constitute an important source of this vitamin. Even if the pandanus usually has only half this amount, the quantity of ascorbic acid obtained when large amounts are eaten would satisfy the daily needs.

#### *Pandanus Paste*

The composition of the pandanus paste may be compared with dried dates which it resembles. The pandanus paste has a little less moisture and therefore a greater energy value (293 calories per 100 grams). The total carbohydrate content is almost identical with dates and the crude fiber content about 1 per cent higher. The reducing sugars of pandanus paste were determined by the Munson-Walker method (Assoc. Off. Agr. Chem., 1950: 506) and found to be 50 per cent (calculated as glucose), which would indicate that about two-thirds of the carbohydrate is in the form of sugars and the remainder includes starch. The protein and fat contents of pandanus paste and dates are low and of little significance. The calcium content of the paste is almost twice that of dates and the phosphorus and iron contents exceed those

of dates, though it may well be that some of the iron in the paste is the result of contamination during preparation and drying. The pandanus paste has almost 20 times the vitamin A value of dates, about the same amount of niacin, and less thiamine and riboflavin. The period of storage prior to the determination of vitamin A was longer than that for the other vitamins as has been indicated. Doubtless all the vitamins were reduced as a result of storage, but since this is a preserved product used for emergencies, the figures which we obtained are probably typical for pandanus paste. Although by the dye titration method pandanus paste had about 1.5 milligrams of ascorbic acid per 100 grams, it may be due to other reducing substances than vitamin C. More work on the paste would be desirable to learn if other samples appear to contain ascorbic acid.

#### *Pandanus Flour*

The sample of pandanus flour from Kapingamarangi which was analyzed is probably typical of the dried products made in other islands judging from the description of its preparation given by Grimble (1933-34: 36, 37, 38) for the Gilbert Islands.

Because the entire soft end is cut off and dried as described earlier, no fibers are removed and the resulting "flour," which resembles fine sawdust, is high in crude fiber (15.0 per cent) and low in moisture (10.8 per cent). (The low moisture content is necessary to insure its good keeping quality.) If the crude fiber is calculated to a product containing 80 per cent of water (comparable to the fresh product), the crude fiber would be reduced to approximately 3.3 per cent, which is much greater than that of even our coarsest vegetables such as cabbage. This is in contrast to the pandanus paste which when recalculated to a fresh basis has less crude fiber than the fresh fruit from the Marshalls (Table 1).

Grimble (1933-34: 39), discussing pandanus flour, states that "the gently purgative qualities of the food are also recognized and

valued by the islander, who uses it freely as an aperient for his children." It is to be expected that a food with such a high fiber content would tend to absorb water and form gas, thus lending bulk to the fecal residues and giving it laxative properties. Just how seriously the fiber would interfere with the absorption of food nutrients is difficult to predict. Digestion experiments upon people accustomed to such a coarse diet would be necessary to determine this point. When the pandanus flour is eaten either with water or with concentrated coconut sap as described by Grimble (1933-34: 39), a much greater percentage of crude fiber would probably be ingested than when the fresh raw or freshly cooked pandanus is nibbled and the fibers are rejected or left clinging to the woody end of the keys.

The calcium content of 797 milligrams per 100 grams seems to be remarkably high and when calculated to 80 per cent moisture would still appear high (180 milligrams per 100 grams). Perhaps much of the calcium is in the fibrous portion, but there is also the possibility that a few grains of coral sand, blown into the pandanus flour in the process of making or drying, could raise the calcium to this high value. Additional analyses are desirable to check this figure. The phosphorus and iron contents when calculated to the fresh basis fall within the range for fresh fruit.

The vitamin A value for pandanus flour was determined in 1948 by rat feeding methods employed in our laboratory with standard vitamin A acetate fed to the controls (Miller, *et al.*, 1951: 106). Either the variety from which this sample was made is low in biologically active carotenoid pigments or as a result of oxidation and dessication the vitamin A value is greatly reduced.

The flour retained its riboflavin content remarkably well and appears to have twice as much of this vitamin as does the paste, on a comparable moisture basis. Riboflavin is sensitive to light and it would be expected that losses would be great when a food is dried

in the sun. Again the original variety of pandanus used in making the flour no doubt influenced the final product. Niacin, being more stable, appears to have been relatively well retained in the pandanus flour as in the paste.

### *Pandanus Seeds*

By use of a hammer and chisel, a sufficient quantity of pandanus seeds were removed from their woody cases to permit determination of only the moisture, protein, and fat contents, which were 47.2 per cent, 10.1 per cent, and 24.7 per cent respectively. Since one seed weighs about half a gram, and the keys available to us had no more than three or four seeds, and often only one or two, more energy is probably required to extract the seeds than could be obtained from eating them.

### SUMMARY AND CONCLUSIONS

In some Pacific islands, especially Kapin-gamarangi and the Marshall, Gilbert, and Ellice Islands, the pandanus fruit is an important seasonal food.

The soft ends of the keys which form the fruits contain a sweet spicy juice or pulp that is eaten in the raw or cooked state. The edible portion is also preserved in two ways—as a dried paste resembling dried dates and as a "flour."

The fresh raw or cooked pandanus contains 14 to 18 per cent carbohydrate in the form of starch and sugars, but has negligible amounts of protein and fat.

The calcium, phosphorus, and iron contents are comparable to temperate climate fruits such as peaches and apricots.

The carotenoid pigments which give the pandanus a rich yellow orange color may be the only source of provitamin A available to the people of these islands when there are few or no green or yellow vegetables in the diet.

Pandanus, like most fruits, is not a rich source of thiamine and riboflavin, though it makes a significant contribution of these fac-



tors in the diet when eaten in large amounts. This is especially true of riboflavin.

Pandanus is a poor source of ascorbic acid, if compared with fruits rich in vitamin C, but when eaten in relatively large amounts, it could meet the needs of the body for this vitamin.

The composition of pandanus paste and pandanus flour are discussed in relation to the fresh samples. Their special worth lies in their energy value as emergency rations or for long sea voyages.

Our work suggests that additional studies on different varieties, followed by selection and propagation by agriculturists, might be profitable. Planting and continued use of the varieties of highest nutritive value that suit particular areas could well be encouraged by all concerned with the health of the people living in the low dry islands of the Pacific. It is especially important to stress that the edible pandanus should not fall into disuse as the result of introducing "store foods" of low nutritive value.

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fruit shown in Figure 1, and Mr. Yoshihiko Kawano, Assistant in Chemistry, H.A.E.S., for taking the photograph; Dr. Leonard Mason, Professor of Anthropology, University of Hawaii, who loaned the beka shown in Figure 3.

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## Some Unusual Fishes From the Central Pacific

JOSEPH E. KING and ISAAC I. IKEHARA<sup>1</sup>

THE PURPOSE OF THIS ARTICLE is to call the attention of ichthyologists to certain rare or uncommon fishes recently collected in the central Pacific by staff members of the Pacific Oceanic Fishery Investigations at Honolulu, and others. These fishes have been deposited with the U. S. National Museum. The photographs included here were taken by E. D. Stroup; Figure 4 was prepared by Tamotsu Nakata.

### SQUALIDAE

The first two species, here placed in the Squalidae following Hubbs and McHugh (1951), were formerly placed in the Dalatiidae, e.g. Bigelow and Schroeder (1948).

#### 1. *Euprotomicrus bispinatus* (Quoy and Gaimard)

One female specimen (Fig. 1) (USNM No. 164176), 161 mm. in total length. Collected March 3, 1948, about 340 miles WNW of Johnston Island at 18°24'N., 175°12'W. in water about 1,000 fathoms deep. Attracted to a light and dip-netted at surface. Collected by M. B. Schaefer aboard M/V "Oregon" operated by Pacific Exploration Company.

*Description:* No anal fin; 2 dorsal fins without spines; snout blunt and broadly rounded; 5 gill openings, all anterior to pectorals; body

nearly cylindrical; eyes lateral without nictitating membrane; a large spiracle present; mouth transverse with a groove extending posteriorly from each end; teeth with only 1 cusp and not serrated; upper teeth narrowly triangular and needle-pointed, lower teeth broader, compressed, and bent outwards; caudal axis scarcely upturned; no subterminal notch evident; end of base of first dorsal fin well in advance of the pelvic insertion; base of second dorsal fin very much longer than that of the first; denticles quadrate, with a central pit; first dorsal fin very much nearer pelvic base than pectoral base; body uniform brownish black (in alcohol after fixation in formalin), outer edges of fins clear. Measurements of the specimen and proportional measurements as per cent of total length are given in Table 1.

Hubbs and McHugh (1951) report the capture of a female *E. bispinatus*, 233 mm. total length, about 500 miles off the California coast. They give a thorough description of the specimen and state that it is ". . . the only extant example of the genus known from the Pacific Ocean and, so far as we know, the only one in an American museum." An earlier specimen collected in the open Pacific "between Honolulu and San Francisco, but nearer to the former" (Eigenmann, 1891) was destroyed in the San Francisco fire, according to Hubbs and McHugh. Since we can find no record of any capture of this species since

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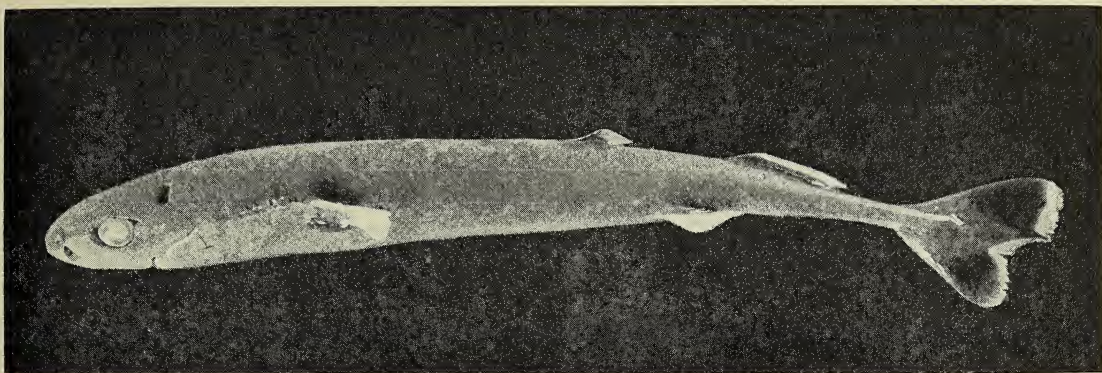


FIG. 1. Lateral view of a 161 millimeter (female) *Euprotomicrus bispinatus* captured at the surface with a dip net at 18°24'N., 175°12'W.



FIG. 2. Lateral view of a 189 millimeter (female) *Isistius brasiliensis* captured by pelagic trawl at 2°09'N., 158°14'W.

1952, at about 11 P.M. aboard M/V "Hugh M. Smith" at 2°04'S., 168°57'W., in water about 3,000 fathoms deep. Collected by Heeny Yuen employing a 1-meter (mouth diameter) zooplankton net in an oblique haul to 200 meters depth.

A female specimen (USNM No. 164175), 179 mm. in total length. Collected May 23, 1954, at about 8:30 P.M. aboard M/V "John R. Manning" at 4°47'N., 161°04'W., in water about 2,000 fathoms deep. Collected by J. E. King and T. S. Hida in a 6-foot Isaacs-Kidd trawl; depth of haul about 100 meters.

A second female (Fig. 2) (USNM No. 164174), 189 mm. in total length. Collected

June 2, 1954, at about 8:30 P.M., aboard M/V "John R. Manning" at 2°09'N., 158°14'W., in water about 1,000 fathoms deep. Collected by J. E. King and T. S. Hida in a 6-foot Isaacs-Kidd trawl with depth of haul about 100 meters. Measurements of this specimen are given in Table 1.

*Description:* No anal fin; 2 dorsal fins, without spines; snout blunt and broadly rounded; 5 gill openings, all anterior to pectorals; body nearly cylindrical; eyes lateral, without nictitating membrane; a large spiracle present; teeth with only 1 cusp and faint indications of serration; teeth of the upper and lower jaw very unlike, the upper are slender and curved



outwards while the lower are much larger and erect, with subquadrate bases and triangular sharp-pointed cusp; caudal axis scarcely upturned; subterminal notch in caudal fin slight; mouth transverse, with fleshy lips and a groove extending backwards and outwards from each end; unlike *E. bispinatus*, the first dorsal fin is displaced backward so that the end of its base is over the origin of the pelvic base; dorsal fin bases nearly equal; denticles quadrate with a median pit; first dorsal fin very much nearer pelvics than pectoral base; body dark brown above (in alcohol after fixation in formalin), pale grayish brown below except for a dark collar across the throat; fins with outer edges clear except the upper lobe of the caudal, which is brown to the margin.

This small oceanic shark, although uncommon, is not nearly as rare as *E. bispinatus*. According to Bigelow and Schroeder (1948), *I. brasiliensis* is distributed throughout the tropical and subtropical belts of all three oceans; however, records of its occurrence in the eastern and central Pacific are few. One specimen was taken by the "Albatross" (Garman 1899) at 2°34'N., 92°06'W. F. D. Bennett (1840) captured two specimens, which he classified as *Squalus fulgens*, in a net towed at the surface; one of these, 10 inches in length, he reported as taken at 2°30'S., 163°W., and the other, 18 inches in length, at 55°N., 110°W. Garman (1899) pointed out the obvious error in the latter position and stated that the actual longitude was 140°W. Later G. Bennett (1860) collected a 5.5-inch specimen, which he classified as *Scymnus* sp., at 2°15'S., 163°W. Jordan and Jordan (1922) report the occurrence of this small shark in Hawaiian waters under the name *Apristurus spongiceps* (Gilbert). Fowler and Ball (1925) state that a specimen classified earlier (Fowler 1923) as *Echinorhinus brucus* (Bonnaterre) in Bernice P. Bishop Museum collections from Hawaiian waters is actually *I. brasiliensis*. All the above names are placed in synonymy with *I. brasiliensis* by Bigelow and Schroeder (1948).

The Bennetts' description of the lumin-

iscence of this fish has been quoted often. This characteristic was not observed in our three specimens, possibly because all three were dead when brought on deck. The luminescence is reported to fade out as the fish dies.

## LOPHOTIDAE

### 3. *Eumecichthys fiski* (Günther) Regan

One specimen (Figs. 3 and 4) (USNM No. 164170), 598 mm. in standard length. Collected June 1, 1954, at about 12:15 P.M. aboard M/V "John R. Manning" at 3°04'N., 159°13'W., in water about 900 fathoms deep. Dip-netted at the surface by Howard Kamaau, fisherman on the "Manning."

*Description:* Body elongate, strongly compressed, nearly of uniform depth throughout, scaleless, snout prolonged as a sword-shaped process bearing near its tip a pronounced plume or crest (Fig. 3); dorsal fin commences at the tip of this process with an extremely long and compressed ray, then continues to the caudal averaging in height about one-fourth the body depth; both jaws are armed with small, hooked teeth; premaxillary non-protractile; eye large; no ventral fins; anal fin rudimentary, base about 3 mm., height less than 1 mm. (Fig. 4); body silvery (in alcohol after fixation in formalin) with about 30 dark bars or blotches, most prominent dorsally; occipital crest and dorsal and caudal fins were crimson in life but faded completely in formalin.

*Fin ray count:* D. 326; P. 13(R), 12(L); C. 10.

Body measurements (in millimeters) and proportional measurements (bracketed) as percentage of standard length: snout to vent, 579.0 (96.7); vent to base of caudal, 20.5 (3.4); caudal fin length, 25.5 (4.3); head length including snout, 64.0 (10.7); snout length in front of mouth, 30.0 (5.0); snout to origin of pectoral, 64.0 (10.7); greatest body height, 21.3 (3.6); greatest body breadth, 7.0 (1.2); pectoral fin length, 13.0 (2.2); pectoral fin base, 5.0 (0.8); dorsal fin height at mid-point of body, 6.0 (1.0); dorsal fin





FIG. 3. Head portion of a 625 millimeter specimen of *Eumecichthys fiski* captured at the surface in a dip net at 3°04'N., 159°13'W.

height at origin of pectoral, 4.0 (0.7); dorsal fin height above vent, 5.0 (0.8); crest height, 83.0 (13.9); eye diameter, 8.0 (1.3).

Details of the capture of this rare fish are perhaps of interest. About midday shortly after starting to haul longline, we (J. E. King and T. S. Hida) noticed a thin "shadow" near the surface just to the rear of the point where the line was emerging from the water. When we finally decided that this was not just the

wake or the shadow of the line but an unusual object in the water, a dip net was hastily obtained and this very rare fish was scooped from the water. After it had lain on a canvas hatch cover for a few minutes, we noticed that a black fluid had been discharged from the vent. Kershaw (1909) and Griffin (1934) have reported that lophotid fishes may emit an inky fluid from the vent when captured.

*Eumecichthys fiski* was described by Günther (1890) as *Lophotes fiski* from a 50-inch specimen that washed up on the shore of Kalk Bay (Atlantic Ocean), South Africa. In this fish the caudal region was mutilated so that Günther did not know the nature of the caudal fin nor whether or not an anal fin was normally present. Apparently no additional examples had appeared in South Africa by the time of the recent revision of "The Sea Fishes

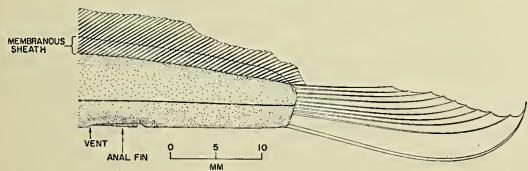


FIG. 4. Tail portion of *Eumecichthys fiski*, same specimen as in Figure 3, with the caudal fin expanded to show the detailed structure of the fin.

of South Africa" by Smith (1953). From our examination of available literature, we conclude that all subsequent collections of *E. fiski*, except for our specimen from the central Pacific, have been from Japanese waters. Kamohara (1949) states that "In Japan a specimen 88.1 cm. in length was collected off Kōchi in 1939 by a worker from the Kōchi Prefectural Fisheries Experiment Station and was reported by Dr. Kiyomatsu Matsubara. This was the first record from Japan. Thereafter it transpired that several specimens had been captured in 1937 off Hagi in Yamaguchi Prefecture, and that it had also been collected earlier in Wakayama Prefecture." [Translated from the Japanese by W. G. Van Campen.] There is no reference to this species in *The Fishes of Oceania* (Fowler, 1928) and its supplements, or in *The Fishes of the Indo-Australian Archipelago*, Vol. V (Weber and De Beaufort, 1929), which includes the Allotriognathi.

#### TRACHYPTERIDAE

##### 4. ? *Trachypterus iris* (Walbaum)

Two specimens (USNM No. 164172), both juveniles; one 84 mm. in standard length (caudal fin broken), the other 109 mm. in standard length (146 mm. total length with caudal depressed to the horizontal). Collected May 4, 1953, at about 8 P.M. aboard M/V "John R. Manning" at 8°32'N., 150°12'W., in water about 2,700 fathoms deep. Collected by W. F. Royce and W. M. Matsumoto in a 10-foot Isaacs-Kidd trawl; depth of haul about 200 meters.

*Description:* Body elongate, strongly compressed, scaleless; dorsal fin extends length of body; caudal fin divided, the larger portion pointing upwards; rays of dorsal bear numerous spinules; lateral line spinous; vent located on mid-ventral line in contrast to the following species; anterior profile steep, almost vertical; mouth protractile; body pale colorless (in alcohol after fixation in formalin).

*Fin ray count:* D. 160 ± 2; P. (broken); V. 5; C. 7 (upper), 5 (lower).

Body measurements (in millimeters) and proportional measurements (bracketed) as percentage of standard length (109 mm.): snout to vent, 70.0 (64.2); vent to base of caudal, 42.0 (38.5); caudal fin length, 34.0 (31.2); greatest body height, 18.0 (16.5); greatest body breadth, 6.0 (5.5).

##### 5. ? *Trachypterus woodi* Smith

One specimen (Fig. 5) (USNM No. 164171), a juvenile, 113 mm. standard length (125 mm. in total length with caudal depressed to the horizontal). Collected May 25, 1954, at about 8:30 P.M. aboard M/V "John R. Manning" at 4°41'N., 159°53'W., in water about 2,000 fathoms deep. Collected by J. E. King and T. S. Hida in a 6-foot Isaacs-Kidd trawl; depth of haul about 100 meters.

*Description:* Body strongly compressed; dorsal fin extends length of body; rays of dorsal with numerous spinules, each ray with a pair of larger spines near its base; rays at anterior end of dorsal show evidence of having been prolonged but are now broken; anterior profile steep but less than vertical; body covered with small, smooth tubercles, particularly prominent in the ventral region; lateral line spinous; no anal fin; caudal fin turned upwards, with no downward projecting portion as in previous specimen; vent located on left side of body about 2 mm. above mid-ventral line (the asymmetrical location of vent in *T. misakiensis* was pointed out by Herre and Herald in 1950); body silvery (in alcohol after fixation in formalin) with scattered dark blotches below dorsal and perhaps seven small blotches extending posteriorly in a line beginning at the upper margin of the eye; fins pink in life, clear in alcohol.

*Fin ray count:* D. 144, P. 12, V. 9, C. 8.

Body measurements (in millimeters) and proportional measurements (bracketed) as percentage of standard length: snout to vent, 78.5 (69.5); vent to base of caudal, 34.0 (30.0); caudal length, 12.5 (11.0); head length, 22.0 (19.4); eye diameter, 7.3 (6.4); snout to origin pectorals, 19.0 (16.7); snout to origin ven-



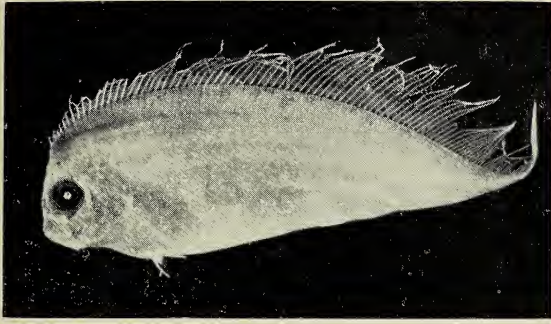


FIG. 5. Lateral view of ?*Trachypterus woodi* Smith captured by pelagic trawl at 4°41'N., 159°53'W.

trals, 23.0 (20.3); greatest body height, 38.0 (33.5); greatest body breadth, 8.0 (7.0); greatest height of dorsal fin, 18.0 (15.9).

Most of the trachypterids examined by ichthyologists have been washed up on shore and usually were in poor condition; our specimens are among the few to be collected in nets, and one of the three, at least, is in excellent condition. These fishes are noted for their change in body proportions during development after the postlarval period (Hubbs, 1926). The juveniles are particularly difficult to identify. On the basis of available literature we have decided that two of our specimens are most likely *T. iris* (Walbaum), which is principally a Mediterranean species, whereas the third resembles *T. woodi* Smith. Although the identification is not certain due to limited library facilities and lack of sufficient reference material, our description, measurements, and the accompanying figure may provide some worthwhile information to those who are interested in the life history of these unusual fishes.

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## Some Marine Algae of the Southern Marshall Islands<sup>1</sup>

E. YALE DAWSON<sup>2</sup>

NO RECORDS OF MARINE ALGAE from the southern atolls of the Marshall Islands have heretofore appeared in the literature. Indeed, our only account of the marine vegetation of this far-flung archipelago is that by W. R. Taylor (1950) dealing with Bikini and other northern atolls of the group.

A recent opportunity to visit several of these atolls with a field team under the leadership of Dr. Bruce W. Halstead resulted in the gathering of a considerable collection of algae from Kwajalein, Jaluit, and Majuro atolls<sup>3</sup>. To this has been added, through the kindness of Dr. M. S. Doty of the University of Hawaii, a large collection obtained by Mr. Leonard Horwitz on Arno Atoll<sup>4</sup>.

These combined collections are so numerous that time has not yet permitted a study of all of the material. What is given here is an annotated list of those specimens which have been examined to date, exclusive of a number of apparently undescribed species and

of certain other plants in need of more critical study. It is hoped that a second part may soon be added to complete this account.

As an aid to field workers who may not have a large algological library at their disposal, an attempt has been made to provide an illustration for each species of which one may not otherwise be at hand. Two handbooks are considered to be so readily available as to serve in conjunction with this paper, namely, Taylor's 1950 account mentioned above, and the writer's recent, fully illustrated treatment of the tropical marine algae of Viêt Nam which appeared in *Pacific Science* Vol. 8, No. 4, 1954. Thus, an illustration is presented here wherever one is not to be found for a given species in one or the other of these works. The style of presentation is the same as in the latter paper. I was aided in the preparation of the drawings by Mrs. Glennis Sayers Clements. The photographs were prepared by Mr. Royford George.

The specimens are cited here by field number preceded by "D." or "H." The former denotes the writer's collections which are deposited in his personal herbarium. The latter denotes those of Mr. Horwitz which are deposited in the Bernice P. Bishop Museum at Honolulu.

### LIST OF STATIONS

The following station numbers are assigned arbitrarily and are not chronological. They serve to provide general locality information

<sup>1</sup> Contribution No. 163 from the Allan Hancock Foundation. Manuscript received May 6, 1955.

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<sup>3</sup> This field work was sponsored in part by a research grant from the National Institute of Health, United States Public Health Service, Bethesda, Maryland, to the School of Tropical and Preventive Medicine, College of Medical Evangelists, Loma Linda, California.

<sup>4</sup> This collection was obtained with financial assistance granted by the Pacific Science Board of the National Academy of Sciences, National Research Council, under contract N7onr-291, Task Order IV, from the Office of Naval Research and a grant from the Pacific Islands Research funds of the University of Hawaii.



on the collections which are cited also by individual field number in the text.

### *Kwajalein Atoll*

Sta. 1. North end of Kwajalein Island along the seaward side of the reef at low tide, Sept. 26, 27, 1954.

Sta. 2. Along the lagoon side of the reef in the vicinity of the first islet north of Kwajalein Island, in up to 1 m. of water at low tide, Sept. 27, 1954.

Sta. 3. Beach drift along seaward reef of north end of Kwajalein Island, Sept. 26, 1954.

Sta. 4. Beach drift along lagoon shore of west end of Kwajalein Island, Sept. 26, 1954.

Sta. 5. Reef at north end of Kwajalein Island at low tide, Oct. 12, 1954.

### *Majuro Atoll*

Sta. 6. On the broad, seaward reef-flat of Uliga Island at low tide, Oct. 10, 12, 1954.

Sta. 7. Along the seaward coralline algal ridge of Uliga Island at low tide, Oct. 10, 1954.

Sta. 8. On the broad seaward reef flat at the northeast end of Dalap Island at low tide, Oct. 11, 1954.

Sta. 9. Narrow seaward reef at east end of Rairikku Island at low tide, Oct. 11, 1954.

Sta. 10. Narrow seaward reef at west end of Enierripu Island at low tide, Oct. 11, 1954.

Sta. 11. Lagoon side of Uliga Island opposite the staff dwellings, Oct. 10, 1954.

### *Jaluit Atoll*

Sta. 12. Seaward edge of reef at Jabor, Jaluit Island, near the old meteorological station at low tide, Sept. 28, 1954.

Sta. 13. From 2-5 meter depths at Sydney Pier, Jaluit Island, Sept. 29, 1954.

Sta. 14. Beach drift along sea wall at Jabor, Jaluit Island, Oct. 2, 1954.

Sta. 15. Along the lagoon side of Kabenbock Island at low tide, Sept. 29, 1954.

Sta. 16. Along the ocean side of Kabenbock Island opposite the pass, mostly in the shelter

of an old shipwreck, at low tide, Sept. 29, 1954.

Sta. 17. In 1-2 meter depths in the bombed out docking area at Jabor, Jaluit Island, at low tide, Sept. 30, 1954.

Sta. 18. Under edges of rocks at medium tide levels and above, lagoon side of Elizabeth Island near the pass, Oct. 1, 1954.

Sta. 19. Edge of the reef of Kabenbock Island along the pass in 1-2 meter depths at low tide, Oct. 3, 1954.

Sta. 20. Patch reef west of Sydney Pier in depths of 2-5 meters at low tide, Oct. 3, 1954.

Sta. 21. Seaward reef, Jaluit Island in vicinity of Jabor, at +2.0-3.0' tide levels, Oct. 4, 1954.

Sta. 22. Lagoon side of Jaluit Island near Sydney Pier, at +2.0-4.0' tide level, in shaded places under overhanging trees, Oct. 4, 1954.

Sta. 23. Enybor Island, a few hundred meters inside the channel, in 1-3 m. depths at low tide, Oct. 7, 1954.

### *Arno Atoll*

The extensive collections of Mr. Leonard Horwitz at Arno Atoll as a member of the Pacific Science Board's 1951 coral atoll team, were made largely in the vicinity of Ine village on Ine Island along the south side of the atoll from late June until late August 1951. Inasmuch as the collection stations on Ine were very numerous they will not be itemized here but treated only as to "Ocean side" or "Lagoon side" of the island. Additional information may be obtained by consulting Mr. Horwitz' original field notebook, a microfilm copy of which is deposited with the Bernice P. Bishop Museum, Honolulu.

Sta. 24. Ocean side of Ine Island, June-August 1951.

Sta. 25. Lagoon side of Ine Island, June-August 1951.

Sta. 26. Ocean side of eastern tip of Tinak Island, August 5, 1951.

Sta. 27. Sandy bottom of lagoon flat off Malel Island, August 4, 1951.

Sta. 28. Lagoon shore of Eonëb-je Island, June–August 1951.

Sta. 29. Upper half of reef pavement of western end of Boki, August 18, 1951.

#### SYSTEMATIC LIST

*Enteromorpha compressa* (L.) Greville  
1830: 180, pl. 18; Setchell and Gardner  
1920: 251, pl. 14, figs. 7–8, pl. 16, fig. 3;  
Bliding 1948: 128, figs. 5–9. *Ulva com-*  
*pressa* Linnaeus 1755: 433 (Sweden)

Fig. 1

MAJURO ATOLL: D. 12769, Sta. 10. This is a short form but apparently typical, agreeing well with both the recent accounts cited above.



FIG. 1. *Enteromorpha compressa*: Habit sketch of a thallus,  $\times 1$ .

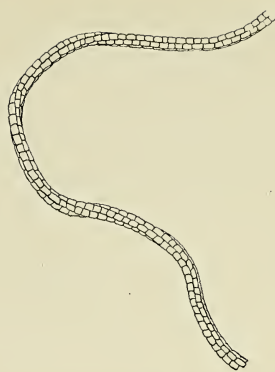


FIG. 2. *Enteromorpha ralfsii*: Part of a filament of D. 12658,  $\times 50$ .

*Enteromorpha kylinii* Bliding 1948: 1, figs. 1–3 (West coast of Sweden); Dawson 1954: 384, fig. 5

KWAJALEIN ATOLL: D. 12658b, Sta. 5.

MAJURO ATOLL: D. 12728, 12740, Sta. 7.

JALUIT ATOLL: D. 13153a, Sta. 21. This material is small and short, but structurally agrees well with this species.

*Enteromorpha ralfsii* Harvey 1851: pl. 282 (Wales); Hamel 1931: 59, fig. 46d

Fig. 2

KWAJALEIN ATOLL: D. 12658, Sta. 5. The filaments of this material are capillary, essentially simple, about  $40\ \mu$  in diameter, and composed of only 3 or 4 rows of cells.

*Enteromorpha clathrata* (Roth) J. Agardh 1883: 153; Bliding 1944: 331, figs. 5–7; Dawson 1954: 384, fig. 6d, e. *Conferva clathrata* Roth 1806: 175 (Baltic Sea)

JALUIT ATOLL: D. 13072, Sta. 15. This is Bliding's Typus II of this variable species. Uniseriate branches are abundant as in the Vietnamese material cited.

ARNO ATOLL: H. 9678, Sta. 25.

*Halicystis pyriformis* Levring 1941: 612, fig. 3 L–P (Juan Fernandez Islands); Dawson 1954: 388, Fig. 8a–c



JALUIT ATOLL: D. 13009, Sta. 12. These are in good agreement in all respects. The largest vesicles are 4 mm. high.

*Valonia aegagropila* C. Agardh 1822: 429 (Venice, Italy); Taylor 1950: 41; Dawson 1954: 388, fig. 8j

KWAJALEIN ATOLL: D. 12567, Sta. 1; D. 12626, Sta. 2; D. 12662, Sta. 5.

MAJURO ATOLL: D. 12747, Sta. 8.

ARNO ATOLL: H. 9333b, 9392a, Sta. 26; H. 9630, Sta. 24.

*Valonia ventricosa* J. Agardh 1887: 96 (St. Croix, Virgin Islands); Dawson 1954: 388, fig. 8e

KWAJALEIN ATOLL: D. 12609, Sta. 2.

JALUIT ATOLL: D. 13056, Sta. 13; D. 13124a, Sta. 19. Plants were abundant in these localities and often 5–6 cm. in diameter.

ARNO ATOLL: H. 9491a, Sta. 28. A few very small plants only 2–3 mm. high, but with the characteristic basal attachment cells.

*Valonia utricularis* (Roth) C. Agardh 1822: 431; Taylor 1950: 41. *Conferva utricularis* Roth 1797: 160, pl. 1, fig. 1 (Mediterranean Sea)

Fig. 3

JALUIT ATOLL: D. 13122, Sta. 19. The specimen is apparently typical, agreeing with

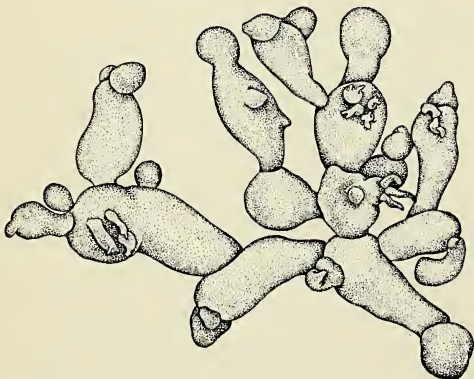


FIG. 3. *Valonia utricularis*: A plant of D. 13122 as seen from the under side,  $\times 2$ .

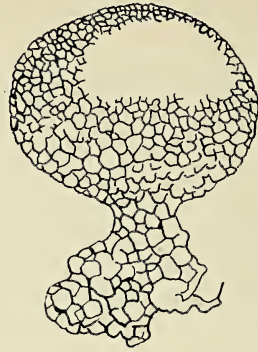


FIG. 4. *Dictyosphaeria bokotensis*: Reproduction of Yamada's original illustration of a specimen of the type collection,  $\times 2$ .

Roth's original figures of dry specimens, poor as they are.

*Dictyosphaeria bokotensis* Yamada 1925: 81, fig. 1 (Pescadores Islands, Formosa)  
Fig. 4

KWAJALEIN ATOLL: D. 12596a, Sta. 1. This collection includes but two specimens, both imperfect from the breaking away of the dome of the hollow thallus. The abundance of long, intracellular spines (trabeculae) and the uniformly small cells of the upper parts of the hollow plants are distinctive. Yamada reports this species from Ant Atoll in the Caroline Islands.

*Dictyosphaeria intermedia* var. *solida* Nasr 1944: 32 (Ghardaqa, Red Sea); Nasr 1947: 29, pl. 1, fig. 1; Taylor 1950: 42 (as *D. intermedia* Weber van Bosse)

Fig. 5



FIG. 5. *Dictyosphaeria intermedia* var. *solida*: Two young specimens from D. 12635,  $\times 2$ .

KWAJALEIN ATOLL: D. 12635, Sta. 2; D. 12557, D. 12596, Sta. 1.

JALUIT ATOLL: D. 13017, Sta. 12.

ARNO ATOLL: H. 9390b, Sta. 26.

Young specimens of our collections correspond closely with Nasr's plant which came from a similar habitat "on the edges of dead corals in places exposed to strong waves and firmly adhering to the substratum by basal rhizoids." In most of the specimens of later stages an irregular development of cavernous invaginations takes place in the gregarious thalli, but hardly the development of a hollow structure in the sense of Weber van Bosse's type plants (1905: 143). Taylor does not speak of his northern Marshall Island specimens as being hollow, but that "it is not infrequent for the organization of the coenocyte into solid thalli to be irregular, even loose, and in such cases the cells are large." On the other hand, D. 12596 includes some examples in which the inner breakdown to the hollow condition has occurred, and which would correspond with *Dictyosphaeria intermedia* var. *intermedia* W. van B. Others are solid like Nasr's plant.

This is probably the plant redescribed by Yamada (1944a) as *D. mutica*.

***Dictyosphaeria versluisii*** Weber van Bosse 1905: 144 (Indonesia); Dawson 1954: 388, fig. 8k, l

KWAJALEIN ATOLL: D. 12560, Sta. 1.

ARNO ATOLL: H. 9265a, Sta. 24; H. 9392, Sta. 26.

***Dictyosphaeria cavernosa*** (Forsk.) Børgesen 1932: 2, pl. 1, fig. 1; Taylor 1950: 43, pl. 27, fig. 2; Dawson 1954: 388, fig. 8i. *Ulva cavernosa* Forskål 1775: 187 (Red Sea)

MAJURO ATOLL: D. 12687, Sta. 6; D. 12719, Sta. 6 (fragmentary material of the large, coarse, flat form illustrated by Taylor); D. 12764, Sta. 9.

JALUIT ATOLL: D. 13083, Sta. 16; D. 13104, Sta. 18.

ARNO ATOLL: H. 9343, Sta. 27; H. 9599b, Sta. 25; H. 9493a, sandy floor of lagoon reef off Matal-En. The large, flat form.

The majority of the specimens of these collections represent the small, hollow, reef-flat form which is almost identical with the Vietnamese plant illustrated by Dawson 1954.

***Boodlea vanbosseae*** Reinbold 1905: 148 (Lucipara Island, Indonesia); Reinbold, in Weber van Bosse 1913: 70, fig. 12

Fig. 6

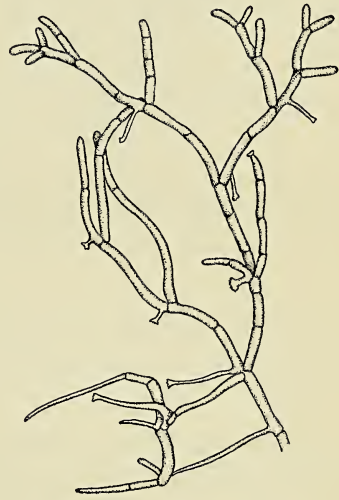


FIG. 6. *Boodlea vanbosseae*: Part of a plant teased out of a clump from H. 9330, showing the rhizoidal branches and fibulae,  $\times 7$ .

ARNO ATOLL: H. 9330, H. 9372a, Sta. 26; H. 9343a, H. 9373b, H. 9374, Sta. 27. This material is manifestly like that described and illustrated by Reinbold. The filaments are 200–300  $\mu$  in diameter and are provided with abundant rhizoidal branches. The haptera, or fibulae, which may be frequent or rather few, arise directly from the ends of cells without the formation of a cross wall except in rare instances.

Yamada (1925: 87) illustrates a plant from Formosa which shows great resemblance to this species and described it as *Cladophora montagnei* Kützinger var. *radicans* Yamada. Although he shows none of the fibulae char-



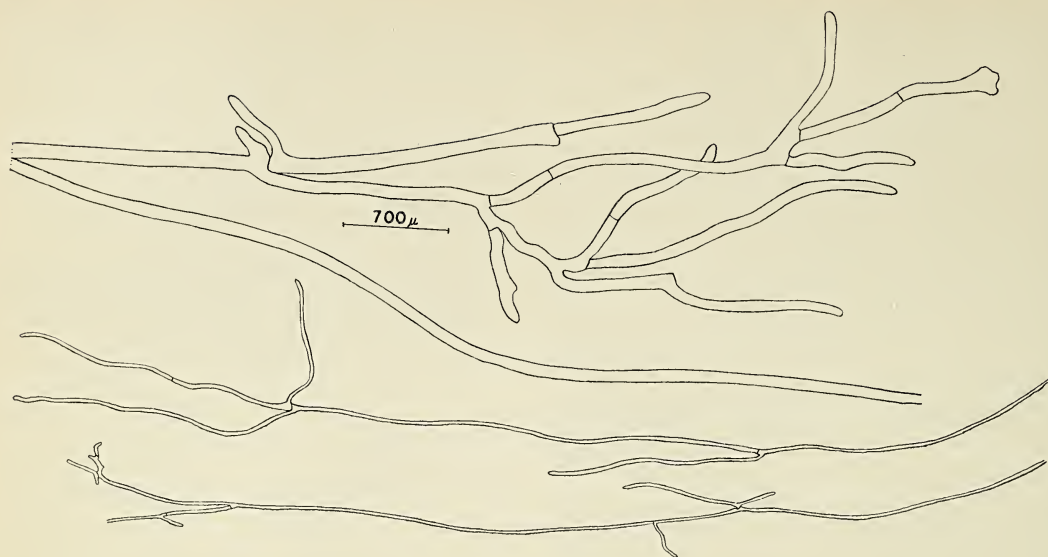


FIG. 7. *Cladophoropsis gracillima*: Reproduction of original illustration of plants of the type collection from Mexico. *a*, Terminal portion of a branched filament showing the manner of septation of branches; *b*, small portion of a skein-like plant to show the extremely long cells and infrequent branching,  $\times 8$ .

acteristic of *Boodlea*, the habit, size, cell shape and rhizoids strongly suggest identity with *Boodlea vanbosseae*.

***Boodlea composita*** (Harv.) Brand 1904: 187; Taylor 1950: 44; Dawson 1954: 390, fig. 9c, d. *Cladophora composita* Harvey 1834: 157 (Mauritius)

KWAJALEIN ATOLL: D. 12587, Sta. 1 (a slender form with ultimate branches only 70  $\mu$  or less in diameter; D. 12613, Sta. 2; D. 12649, Sta. 3; D. 12659, Sta. 4.

MAJURO ATOLL: D. 12698, 12701, Sta. 6.

JALUIT ATOLL: D. 13106, Sta. 18; D. 13139, Sta. 20.

ARNO ATOLL: H. 9493c, Sta. 28; H. 9581c, Sta. 25.

***Struvea anastomosans*** (Harv.) Piccone and Grunow, ex Piccone 1884a: 20; Dawson 1954: 390, fig. 8g. *Cladophora ? anastomosans* Harvey 1859, pl. 101 (Fremantle, West Australia)

KWAJALEIN ATOLL: D. 12603, Sta. 2; D. 12671, Sta. 5.

JALUIT ATOLL: D. 13047, Sta. 13.

***Cladophoropsis gracillima*** Dawson 1950a: 149, figs. 12-13 (Punta Palmilla, Baja California, Mexico)

Fig. 7

ARNO ATOLL: H. 9327, H. 9333a, Sta. 26.

This material, with its very long cells and thick, stratified cell walls (often 10  $\mu$  or more) is identical with the type of this tropical Mexican species. The filaments are mostly 70-100  $\mu$  in diameter and remotely branched and septate except in the outer parts of some filaments which are septate much as shown in Dawson's figure reproduced above. This species has heretofore been known only from the type material.

***Cladophoropsis sundanensis*** Reinbold 1905: 147 (Timor); Reinbold, in Weber van Bosse 1913: 77, fig. 18; Dawson, Aleem and Halstead 1955: 10

Fig. 8

KWAJALEIN ATOLL: D. 12593, Sta. 1.

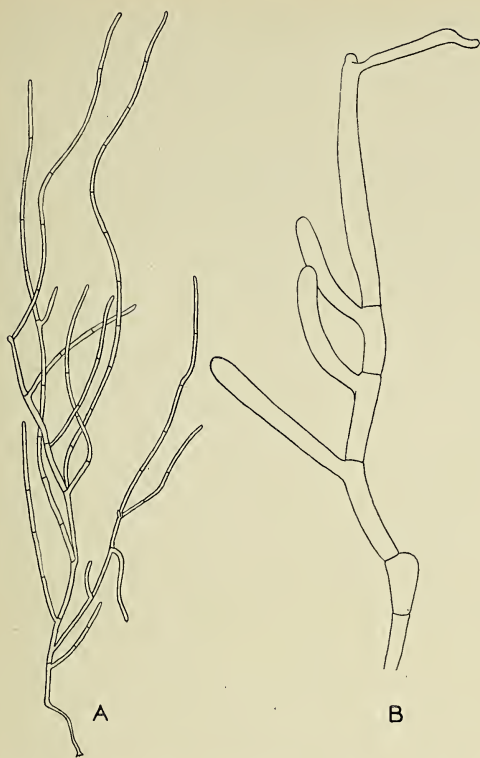


FIG. 8. *Cladophoropsis sundanensis*: a, Habit of part of a plant of D. 12712,  $\times 7.5$ ; b, detail of branching of part of a plant of D. 12593,  $\times 20$ .

MAJURO ATOLL: D. 12699, 12711, Sta. 6; D. 12712, 12714, in abundant, large mats along the lagoon shore of Dalap Island. This slender, laxly branched form is most probably the same as the plant attributed to *Cladophoropsis zollingeri* by Taylor (1950). While the diameter of *C. sundanensis* ranges from about 60 to 130  $\mu$ , or sometimes to 175  $\mu$ , *C. zollingeri* is a coarser plant in which the type specimen according to Howe (1914) has filaments 215–315  $\mu$  in diameter.

JALUIT ATOLL: D. 13012, Sta. 12.

ARNO ATOLL: H. 9490, Sta. 28. The filaments in these are mostly 80–90  $\mu$  in diameter; the occurrence of septa at the base of lateral branches is not infrequent, although in most instances the characteristic *Cladophoropsis* type of branching obtains.



FIG. 9. *Siphonocladus rigidus*: Habit of a plant of D. 12574,  $\times 5$ .

*Siphonocladus rigidus* Howe 1905a: 245, pls. 13–14 (Bahamas Islands)

Fig. 9

KWAJALEIN ATOLL: D. 12574, Sta. 1. Although this material is somewhat depauperate, it is in excellent agreement with Howe's plant which heretofore has been recorded only from the Atlantic Caribbean region.

ARNO ATOLL: H. 9333d, Sta. 24; H. 9505, Sta. 28. These are more repent in habit than either Atlantic or Kwajalein specimens seen but hardly to be distinguished otherwise.

*Anadyomene wrightii* Gray 1866: 48, pl. 44, fig. 5 (Ryukyu Archipelago); Dawson 1954: 390, fig. 9e

JALUIT ATOLL: D. 13105, Sta. 18. Most of these specimens from high intertidal rock clefts are dwarfish, but some are sufficiently well developed to show satisfactory comparison with Japanese and Vietnamese examples.

ARNO ATOLL: H. 9190, Sta. 24; H. 9491, Sta. 28. Small, but good, well developed material.





FIG. 10. *Rhipidiphyllon reticulatum*: Part of a plant from H. 9372b to show branching,  $\times 12.5$ .

**Rhipidiphyllon reticulatum** (Askenasy) Heydrich 1894: 281, pl. 15, fig. 1; Taylor 1950: 47; Børgesen 1924: 251, figs. 3-4. *Anadyomene reticulata* Askenasy 1888: 5, pl. 2, fig. 7 (Dirk Harteg Isl., West Australia)

Fig. 10

ARNO ATOLL: H. 9372b, H. 9486, H. 9487a, Sta. 28; H. 9444a, Sta. 24.

**Microdictyon okamura** Setchell 1929: 553, fig. 76-84 (Ryukyu Islands); Yamada 1934: 40, figs. 6-7; Taylor 1950: 46, pl. 27, fig. 1

Fig. 11a

KWAJALEIN ATOLL: D. 12551, Sta. 1; D. 12627, Sta. 2.

JALUIT ATOLL: D. 13101, Sta. 18.

ARNO ATOLL: H. 9592b, Sta. 25 (cell walls mostly under  $7 \mu$ ); H. 9390a, Sta. 26.

The cell walls in this species are very thin, about 3-5 (6)  $\mu$  thick, compared to *M. setchellianum* in which they are mostly over  $10 \mu$  thick, sometimes up to 16-20  $\mu$ . The

segment and mesh diameters of the two species are similar, although some forms of *M. setchellianum* are considerably coarser. Setchell's illustrations are ample and explicit.

**Microdictyon setchellianum** Howe 1934: 38 (Honolulu, Hawaii); Egerod 1952: 366, pl. 33, fig. 6c-g; Setchell 1929: 561, figs. 85-92 (as *M. velleyanum*)

Fig. 11b

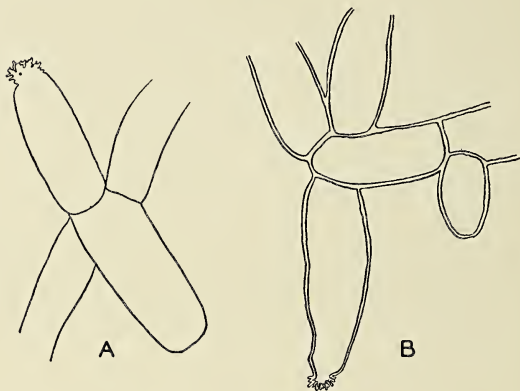


FIG. 11. a, *Microdictyon okamura*: A few cells, one with fibula, showing the thin walls,  $\times 38$ ; b, *Microdictyon setchellianum*: A few cells, one with fibula, showing the thick walls,  $\times 38$ .

ARNO ATOLL: H. 9372, Sta. 26; H. 9345a, Sta. 26 (cell walls mostly 7-10  $\mu$  thick); H. 9343b, Sta. 27; H. 9495, Sta. 28 (a very dark green, coarse form).

**Microdictyon pseudohapteron** Gepp and Gepp 1908: 165, pl. 22, figs. 1-4 (Western Indian Ocean); Setchell 1929: 549, figs. 71-75

Fig. 12

ARNO ATOLL: H. 9628a, Sta. 24. A single small tufted plant is present of this species, but is readily distinguished by its relatively delicate frond from the coarser *M. okamura* and *M. setchellianum* of which the former grew in the same immediate locality. The filaments reach a maximum of somewhat less than 200  $\mu$  while the outer cells are only about 100  $\mu$  in diameter.

**Rhizoclonium samoense** Setchell 1924:  
177, fig. 42 (Tutuila, Samoa)  
Fig. 13a

JALUIT ATOLL: D. 13154, Sta. 22, at highest intertidal level under shade of trees with partial fresh-water influence. This material with filaments 45–70  $\mu$  in diameter is in close agreement with Setchell's plant which came from the same kind of habitat in Samoa and is of similar filament diameter (45–80  $\mu$ ). Whether his species is really distinct from the widespread *R. tortuosum* (Dillw.) Kütz. seems, however, to be doubtful.

ARNO ATOLL: H. 9487, Sta. 28, from deep under an overhanging beach rock slab, may be the same as the above, although a more densely intertwined, pulvinate rather than fleecy mass is formed of somewhat more branched filaments.

**Chaetomorpha indica** Kützing 1849: 376  
(Tranquebar, southeast India); Børgesen  
1935: 12, fig. 2; Dawson 1954: 386, fig.  
6f, g

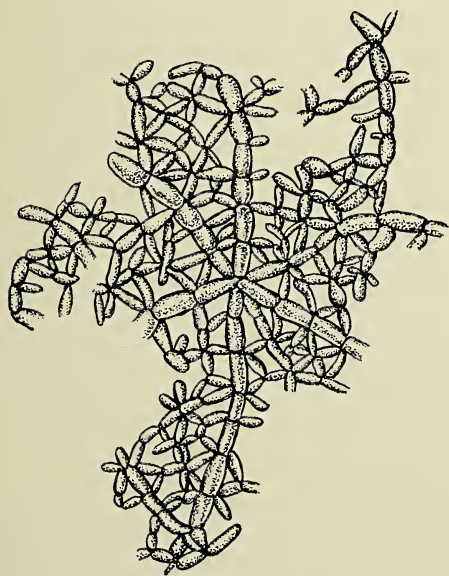


FIG. 12. *Microdictyon pseudobapteron*: Reproduction of original illustration of the Gepp's Indian Ocean type,  $\times 8$ .

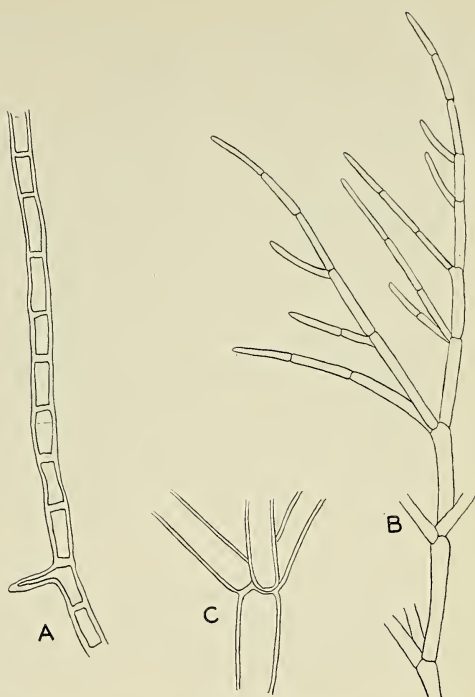


FIG. 13. *a*, *Rhizoclonium samoense*: A small part of a single filament from D. 13154,  $\times 66$ . *b*, *c*, *Cladophora crystallina*, D. 12658: *b*, An upper part of a plant to show branching,  $\times 50$ ; *c*, a lower part of the same plant,  $\times 50$ .

KWAJALEIN ATOLL: D. 12661, Sta. 5, in good agreement with both the Bombay and Viêt Nam plants cited above.

MAJURO ATOLL: D. 12745a, Sta. 8. This is apparently an entangled, partly free form of this species growing with *Cladophoropsis sundanensis*.

**Cladophora crystallina** (Roth) Kützing  
1845: 213; Hamel 1929: 53, fig. 12B. *Conferva crystallina* Roth 1797: 196 (Baltic Sea)

Fig. 13b, c

KWAJALEIN ATOLL: D. 12658a, Sta. 5, mixed with *Enteromorpha kylinii* and *E. ralfsii*. With a diameter of about 110  $\mu$  below and ultimate branches of about 20  $\mu$  diameter, this corresponds excellently with Hamel's interpretation of this species although only about 2–3 cm. in height. The small diameter



and pectinate branching of the ultimate segments are characteristic together with the gradually enlarged lower segments.

*Cladophora socialis* Kützing 1849: 416; 1854, Tab. Phyc. 4: pl. 71 (Tahiti); Børgesen 1946: 28. *Cladophora patentiramea* var. *longiarticulata* Reinbold, in Weber van Bosse 1913: 84; Dawson 1954: 388, fig. 7e

JALUIT ATOLL: D. 13088, Sta. 16. The present material is much like the Kützing type in habit, but has longer cells. Børgesen's study of similar plants from Mauritius has led to his conclusion that Reinbold's Indonesian plant is only a form of *C. socialis* with longer cells.

*Bryopsis indica* Gepp and Gepp 1908: 169, pl. 22, figs. 10–11 (Coetivy Reef, Indian Ocean); Taylor 1950: 50

Fig. 14a

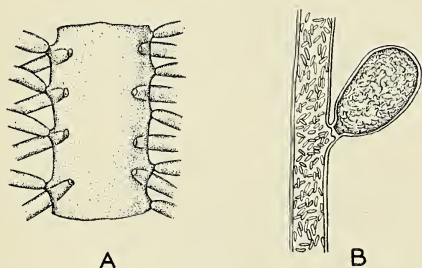


FIG. 14. a, *Bryopsis indica*: Reproduction of the Gepp's original illustration of a small portion of the type showing the double row of pinnae,  $\times 37$ . b, *Derbesia ryukiensis*: A single sporangium from H. 9520,  $\times 187$ .

ARNO ATOLL: H. 9472, H. 9543, Sta. 24. These specimens agree well with this Indian Ocean species recently reported by Taylor from Eniwetok Atoll. They are symmetrically branched like the type, not secund near the tip as Taylor's. The double row of pinnae on either side is distinctive.

*Bryopsis pennata* Lamouroux 1809a: 134, pl. 3, fig. 1a, b (Antilles); Dawson 1954: 393, fig. 11b

KWAJALEIN ATOLL: D. 12602, Sta. 2 (with partly tetrastichous pinnae which are very long); D. 12667, Sta. 5.

MAJURO ATOLL: D. 12709, Sta. 6; D. 12715, lagoon shore of Enierippu Island in 2–5 ft. at low tide.

JALUIT ATOLL: D. 13052, Sta. 13; D. 13067, Sta. 15; D. 13127, Sta. 19; D. 13153, Sta. 21.

ARNO ATOLL: H. 9176, H. 9219, H. 9260, Sta. 24.

*Derbesia ryukyuensis* Yamada and Tanaka 1938: 64, fig. 5 (Pinai, Yonakuni Island, Ryukyu Archipelago)

Fig. 14b

ARNO ATOLL: H. 9520, H. 9542, H. 9551, Sta. 24. This richly developed material from the reef drop-off is in very good agreement with the type as illustrated (l.c.), especially as to details of structure of the sporangia. The specimens are somewhat smaller throughout as to diameter of filaments (about  $25\ \mu$ ) and size of sporangia (about  $80\ \mu$  long), but on the other hand some of them are much more extensively developed vegetatively, up to 7–9 cm. long and forming an entangled skein.

*Derbesia marina* (Lyngbye) Solier 1847: 158. *Vaucheria marina* Lyngbye 1819: 79, pl. 22, fig. A (Denmark)

Fig. 15

JALUIT ATOLL: D. 13048, 13057, Sta. 13. This material is somewhat smaller than average, but is larger than the plants described as *Derbesia minima* Weber van Bosse. The shape, proportions and pedicellation of the sporangia agree well with *D. marina*.

*Derbesia attenuata* Dawson 1954: 390, fig. 9a, b (Nhatrang, Việt Nam)

MAJURO ATOLL: D. 12685, Sta. 6; D. 12750, Sta. 8.

JALUIT ATOLL: D. 13146, Sta. 20; (a confusing mixture in which some of the plants seem to grade into a *Bryopsis*-like form).

ARNO ATOLL: H. 9165b, H. 9290a, Sta. 24. Material corresponding with the type has

recently been recognized at Isla Socorro, Mexico as well as at these several Marshall Island stations. It is suspected that it is not an autonomous species, but a stage in the development of some other green alga.

*Caulerpa racemosa* var. *macrophysa* (Kütz.) Taylor 1928: 101, pl. 12, fig. 3, pl. 13, fig. 9; Taylor 1950: 63; Dawson 1954: 393, fig. 10c. *Chauvinia macrophysa* Kützinger 1857, Tab. Phyc. 7: 6, pl. 15 II (Central America)

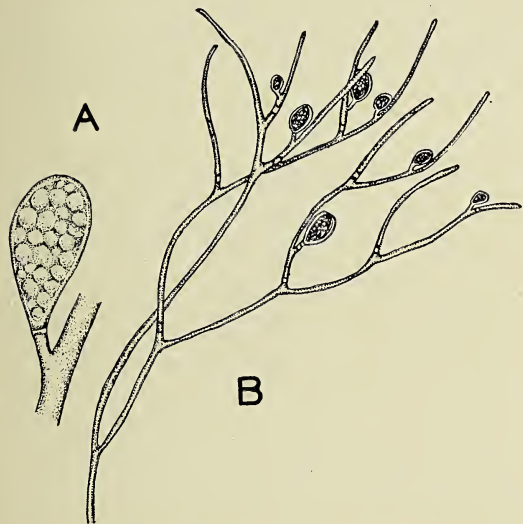


FIG. 15. *Derbesia marina*: a, Mature sporangium,  $\times 300$ ; b, habit of part of a fertile plant,  $\times 17$  (redrawn from Saunders).

JALUIT ATOLL: D. 13166, Sta. 23.

ARNO ATOLL: H. 9576b, Sta. 25.

*Caulerpa racemosa* var. *turbinata* (J. Ag.) Eubank 1946: 420, fig. 20–q. *Caulerpa clavifera* var. *turbinata* J. Agardh 1837: 173 (Red Sea)

Fig. 16a

KWAJALEIN ATOLL: D. 12556, Sta. 1. These plants have ramuli of variable form on a single individual.

*Caulerpa racemosa* var. *peltata* (Lam.) Eubank 1946: 421, fig. 2r, s. *Caulerpa pel-*

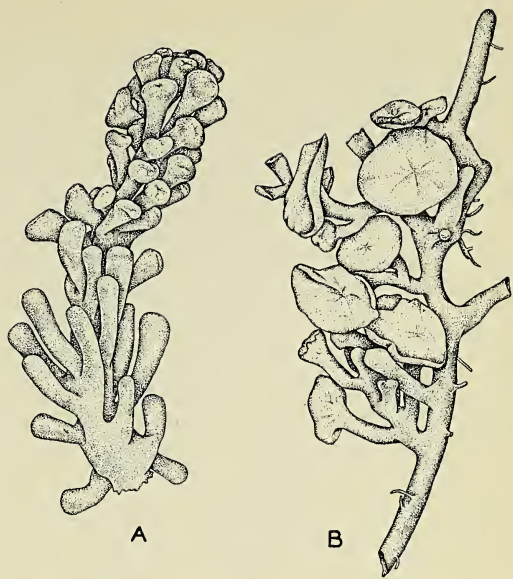


FIG. 16. a, *Caulerpa racemosa* var. *turbinata*: A small upper part of a plant of D. 12556,  $\times 4$ ; b, *Caulerpa racemosa* var. *peltata*: A small part of a plant of D. 13119,  $\times 4$ .

tata Lamouroux 1809b: 145; Taylor 1950: 65

Fig. 16b

KWAJALEIN ATOLL: D. 12562, Sta. 1; D. 12624, Sta. 2; D. 12675, Sta. 5.

MAJURO ATOLL: D. 12720, lagoon shore of Enierippu Island.

JALUIT ATOLL: D. 13029, Sta. 12; D. 13119, Sta. 19.

ARNO ATOLL: H. 9682, Sta. 25.

*Caulerpa taxifolia* (Vahl) C. Agardh 1822: 435; Yamada 1934: 67, figs. 36–37. *Fucus taxifolius* Vahl 1799: 36 (West Indies)

Fig. 17

ARNO ATOLL: H. 9684, Sta. 25. Rather dwarfish material but identical with Ryukyu specimens illustrated by Yamada.

*Caulerpa vickersiae* Børgesen 1911: 129 (Virgin Islands). Dawson 1954: 392, fig. 9f (as *C. ambigua* Okam.); Eubank 1946: 410, pl. 22, fig. 2a, b (as *C. ambigua*)

Fig. 18





FIG. 17. *Caulerpa taxifolia*: Habit of part of a plant,  $\times 1.5$  (redrawn from Yamada).

KWAJALEIN ATOLL: D. 12564a, Sta. 1. These specimens are in full agreement with Børgesen's West Indian plant and with specimens from Viêt Nam reported under the name *C. ambigua*. The fortunate discovery in the reef turf on Kwajalein Island of specimens which match the original figures of Okamura's *C. ambigua* and which show such clear distinction from *C. vickersiae* growing in the same habitat, has led me to the following conclusions regarding these two names which have been discussed in recent years alternately by Eubank-Egerod and by Børgesen. Børgesen was right in his interpretation that Okamura had mixed two species in preparing his initial account of *C. ambigua* Okamura (1897: 4, pl. 1, figs. 3-12) and that his description and figures applied mainly to the one of these having basally contracted branches. This plant with basally contracted, multifarious branchlets, unlike those of *C. vickersiae* Børgesen, was maintained by Okamura as representative of his species up to the time of his death (see Okamura 1936:



FIG. 18. *Caulerpa vickersiae*: Part of a plant of D. 12564a showing the regular distichous branching,  $\times 9$ .

105, fig. 54). The figures presented here show how clearly distinct are these two plants which are sometimes found growing side by side in the same reef turf.

JALUIT ATOLL: D. 13022, Sta. 12. This small specimen is for the most part bifurcately and multifariously branched. It shows considerable superficial resemblance to *C. ambigua* and is apparently like the multifariously branched Hawaiian specimens confused by Eubank with *C. ambigua*. It is distinct from *C. ambigua* in lacking the swollen, basally contracted branchlets and in being irregularly and incompletely multifarious.

*Caulerpa ambigua* Okamura 1897: 4, pl. 1, figs. 3-8, 11-12 (Ryukyu Islands); Okamura 1936: 105, fig. 54  
Fig. 19

KWAJALEIN ATOLL: D. 12673a, Sta. 5. See comments above under *C. vickersiae*.

*Caulerpa antoensis* Yamada 1944b: 27, pl. 1, fig. 1 (Ant Atoll, near Ponape, Caroline Islands)

Fig. 20

MAJURO ATOLL: D. 12692, Sta. 6; D. 12725, Sta. 7. This material is identical with specimens seen by the writer from Saipan and probably is the same as that which Taylor

(1950: 55, pl. 28, fig. 2) has described from Rongelap Atoll as *Caulerpa arenicola*. Some of the specimens are more irregularly branched than others.

ARNO ATOLL: H. 9681a, Sta. 25.

*Caulerpa elongata* Weber van Bosse 1898: 271, pl. 21, figs. 5–6 (Macassar, Indonesia); Taylor 1950: 54, pl. 28, fig. 1, pl. 52, fig. 1

ARNO ATOLL: H. 9592, H. 9599f, H. 9601, Sta. 25. This is in full agreement with the species as recently reported by Taylor from Bikini Atoll. Both distichous and polystichous branching occur on the plants of these collections.



FIG. 19. *Caulerpa ambigua*: A plant of D. 12673a showing the multifarious branching and basally contracted branchlets,  $\times 8$ .

*Caulerpa verticillata* J. Agardh 1847: 6 (Atlantic Mexico); Taylor 1950: 54; Dawson 1954: 392, fig. 10b

MAJURO ATOLL: D. 12783, Sta. 11.

ARNO ATOLL: H. 9059b, H. 9681, H. 9685, Sta. 25.

*Caulerpa urvilliana* Montagne 1845: 21 (Toud Island, Torres Straits ?); Taylor 1950: 60, pl. 31, fig. 1, pl. 32, fig. 1

Fig. 21



FIG. 20. *Caulerpa antioensis*: Part of a plant from D. 12692 showing many sand grains adhering to rhizoids,  $\times 5$ .

KWAJALEIN ATOLL: D. 12595, Sta. 1; D. 12656, Sta. 4.

MAJURO ATOLL: D. 12696, Sta. 6.

ARNO ATOLL: H. 9581b, Sta. 25; H. 9373a, Sta. 27; H. 9493, Sta. 28; H. 9614a, Sta. 29.

The material of these collections is vari-



FIG. 21. *Caulerpa urvilliana* var. *urvilliana* f. *tristicha*: A small upper part of a plant of D. 12656,  $\times 3$ .



able, some being dwarfish and depauperate while others are vegetatively well developed. The better developed ones correspond with what Taylor calls var. *typica* f. *tristicha* (J. Ag.) Weber van Bosse.

*Caulerpa sertularioides* (Gmelin) Howe 1905b: 576. *Fucus sertularioides* Gmelin 1768: 151, pl. 15, fig. 4 ("America")  
Fig. 22



FIG. 22. *Caulerpa sertularioides*: Habit of a plant from D. 12655,  $\times 1.5$ .

KWAJALEIN ATOLL: D. 12655, Sta. 4.

*Caulerpa serrulata* (Forsk.) J. Agardh, emend. Børghesen 1932: 5, pl. 1, fig. 2; Taylor 1950: 57, pl. 29, fig. 1, pl. 30; Dawson 1954: 393, fig. 10a. *Fucus serrulatus* Forskål 1775: 179 (Red Sea)

Fig. 23

KWAJALEIN ATOLL: D. 12563, Sta. 1; D. 12680, Sta. 5.

MAJURO ATOLL: D. 12785, Sta. 11. This material corresponds with the type variety of the species which Taylor has called *C. serrulata*



FIG. 23. *Caulerpa serrulata* var. *serrulata* f. *spiralis*: Part of a plant from H. 9225,  $\times 3.5$ .

var. *typica* f. *serrulata* (Weber van Bosse) Gilbert.

JALUIT ATOLL: D. 13064, Sta. 15; D. 13144, Sta. 21.

ARNO ATOLL: H. 9159, H. 9550, Sta. 24. These correspond with var. *boryana* (J. Ag.) Gilbert as reported and illustrated by Taylor (1950: 59, pl. 30, fig. 2). H. 9225, H. 9262, Sta. 24. These correspond with var. *typica* f. *spiralis* (Weber van Bosse) Gilbert as interpreted by Taylor in his text although the name "var. *typica* f. *angusta*" is employed in his key.

*Codium arabicum* Kützinger<sup>5</sup> 1856, Tab. Phyc. 6: 35, pl. 100, fig. 2 (Tor, Sinai Peninsula, Gulf of Suez, Egypt)

Fig. 24

KWAJALEIN ATOLL: D. 12550, Sta. 1.

MAJURO ATOLL: D. 12758, Sta. 9; D. 12775, Sta. 10.

JALUIT ATOLL: D. 13081, Sta. 16.

ARNO ATOLL: H. 9599a, Sta. 25.

<sup>5</sup> This and all other *Codium* material cited here was determined by Dr. P. C. Silva.

*Codium ovale* Zanardini 1878: 37 (New Guinea)

Fig. 25

KWAJALEIN ATOLL: D. 12598, Sta. 2.

MAJURO ATOLL: D. 12778, Sta. 11.

*Codium geppii* O. C. Schmidt 1923: 50, fig. 33 (Malaya); Dawson 1954: 395, fig. 13k

Fig. 26

KWAJALEIN ATOLL: D. 12552, Sta. 1; D. 12606, Sta. 2. Dr. Silva, in a personal communication, says of these plants: "This material is certainly to be assigned to the *geppii* complex, but just where it fits into the picture I cannot say for the moment. It is closer to *C. edule* from Hawaii than to typical *geppii* from Indonesia; that is, the branches are thicker and less markedly divaricate than in typical *geppii*. It matches material from the Philippines and from Okinawa very nicely."

MAJURO ATOLL: D. 12733, Sta. 7; D. 12744, Sta. 8.

JALUIT ATOLL: D. 13002, Sta. 12.

*Pseudochlorodesmis furcellata* (Zarnard.) Børgesen 1925: 78, figs. 30–34; Dawson 1954: 395, fig. 11c. *Bryopsis furcellata* Zanardini 1843: 60 (Adriatic Sea)



FIG. 25. *Codium ovale*: Habit of a plant from D. 12778,  $\times 2$ .

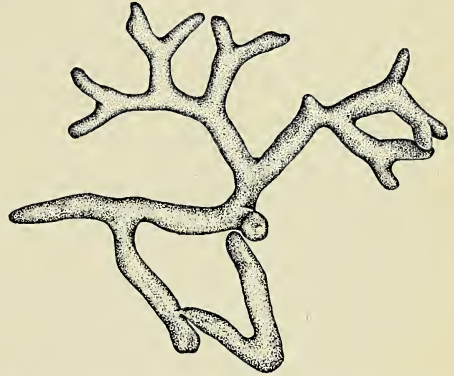


FIG. 26. *Codium geppii*: Habit of part of a plant from D. 12606,  $\times 1$ .

KWAJALEIN ATOLL: D. 12570a, Sta. 1.

*Geppella mortensenii* Børgesen 1940: 55, figs. 16–18 (Mauritius)

Fig. 27

ARNO ATOLL: H. 9462, Sta. 24; H. 9581g, Sta. 25. Several small plants are present in these collections of mixed small algae. They are somewhat less broadly flabellately developed than Børgesen's type, but otherwise are identical in size and structure with this species known heretofore only from Mauritius.

*Avrainvillea nigricans* Decaisne 1842: 108 (near Guadeloupe, West Indies); Taylor 1950: 69, pl. 34, fig. 2

ARNO ATOLL: H. 9576a, Sta. 25. Two poor, somewhat fragmentary specimens are in agreement with Taylor's material from Rongerik



FIG. 24. *Codium arabicum*: Habit of a plant from D. 12758,  $\times 1.5$ .



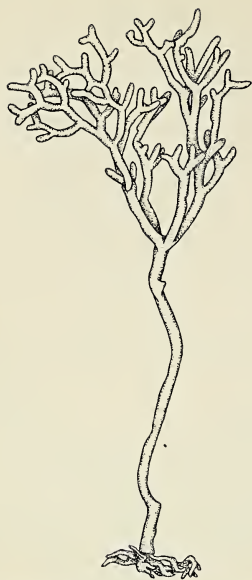


FIG. 27. *Geppella mortensenii*: Habit of a plant from H. 9462,  $\times 10$ .

and Bikini atolls and assigned to this West Indian species with some doubt. In view of the occurrence of a number of other tropical species both in the Marshall Islands and the West Indies, this distribution does not seem extraordinary. In any case, the characters of the present materials do not suggest a distinction from this species as elaborately treated by A. and Ethel Gepp (1911).

***Rhipilia orientalis*** A. and Ethel Gepp 1911: 57, figs. 134–136 (Borneo Bank); Taylor 1950: 72, pl. 36, fig. 1

ARNO ATOLL: H. 9185, H. 9167, Sta. 24. These fine specimens from the reef drop-off are in excellent agreement with those of the original account, even as to the thin, "translucent" character of some of the thalli. The thallus filaments are more slender in general, ranging from  $18\text{--}30\ \mu$ , but the variation between and within specimens would suggest that this is an environmental response. Like Taylor's northern Marshall Island specimens, the tenacula vary from two- to four-pronged. Yamada (1944a) has described a species,

*Rhipilia micronesica*, from Ant Atoll, Caroline Islands, basing its distinction from *R. orientalis* on more slender frond filaments ( $20\text{--}32\ \mu$ ) and the tentacular processes occurring only in pairs. The variability of the present specimens in these respects suggests that Yamada's plants are probably essentially the same as some of ours and doubtfully distinct from *R. orientalis*. Examination of more material from the type locality will be necessary to settle this point.

Horwitz 9360, Sta. 25, seems to represent a large, heavier, greener form of *R. orientalis*. Although taken on the reef flat in full light, the plants are of size and color suggesting *R. diaphana* Taylor, a deep-water plant. The structure so corresponds with *R. orientalis* as to preclude assignment to one of the other species such as *R. tomentosa* or *R. tenaculosa*.

***Udotea palmetta*** Decaisne 1842: 380, pl. 17, fig. 15 (Galega Island, Western Indian Ocean ?); A. and Ethel Gepp 1911: 122, figs. 10, 11, 54; Børgesen 1940: 59

Fig. 28

KWAJALEIN ATOLL: D. 12554, Sta. 1.

MAJURO ATOLL: D. 12743, Sta. 8.

ARNO ATOLL: H. 9576, H. 9599c, Sta. 25; H. 9340a, H. 9390e, Sta. 26.

Most of the specimens are much smaller than the type illustrated by the Gepps, but among the Arno collections are some specimens under H. 9576 which are almost identical in size with the type and also in satisfactory agreement on anatomical details.

From Taylor's (1950) discussion and illustrations of plants attributed to *U. indica* one gets the impression that they should instead be referred to *U. palmetta*, for he says "but the blade filament appendages are often much longer and less blunt [than in *U. indica* figured by the Gepps], never truncate."

***Udotea javensis*** (Mont.) A. and Ethel Gepp 1904: 363; Taylor 1950: 73; Dawson 1954: 395, fig. 13 b, c. *Rhipidosiphon javensis* Montagne 1842: 15 (Java)

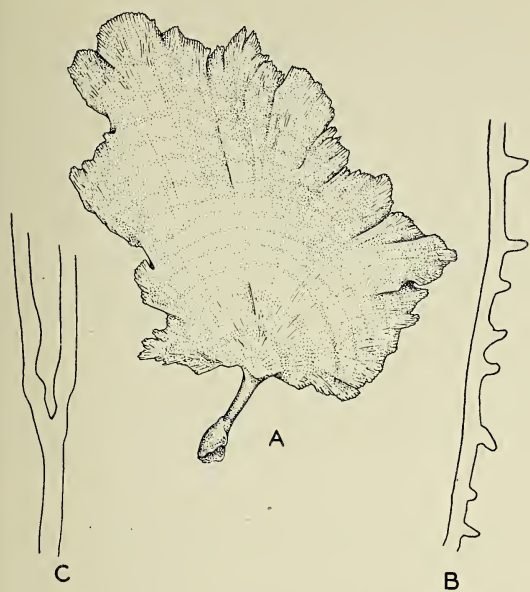


FIG. 28. *Udotea palmetta*: a, Habit of a relatively large plant from H. 9576,  $\times 1$ ; b, exposed part of a thallus filament showing the lateral appendages,  $\times 114$ ; c, part of an inner thallus filament showing a dichotomy,  $\times 114$ .

MAJURO ATOLL: D. 12716, lagoon side of Enierippu Isl.; D. 12779, Sta. 11.

JALUIT ATOLL: D. 13046, Sta. 13.

*Tydemannia expeditionis* Weber van Bosse 1901:139 (Indonesia); Taylor 1950: 73, pl. 38, fig. 1; Srinivasan 1954: 247–255

JALUIT ATOLL: D. 13060, Sta. 13; D. 13123, D. 13128, Sta. 19 (includes a plant showing the flabellate form of the thallus); D. 13163, Sta. 23.

*Halimeda fragilis* Taylor 1950: 88, pl. 48, fig. 2 (Eniwetok Atoll, Marshall Islands)

ARNO ATOLL: H. 9160, Sta. 24; H. 9673, Sta. 25. These specimens from reef drop-offs are in full agreement with Taylor's account.

*Halimeda monile* (Solander) Lamouroux 1812: 186; Taylor 1950: 92, pl. 50, fig. 1. *Halimeda incrassata* f. *monilis* (Solander) Barton 1901: 27, pl. 4, fig. 40; Yamada 1941:

118, fig. 12. *Corallina monile* Solander 1786: 110, pl. 20, fig. c (Jamaica)

KWAJALEIN ATOLL: D. 12653, Sta. 4; D. 12670, Sta. 5.

MAJURO ATOLL: D. 12755, Sta. 8. This appears to be a short, much-branched, depauperate form of this plant resembling the Indonesian specimens illustrated by Barton (1901: pl. 4, fig. 44) as *H. incrassata* f. *pusilla*.

*Halimeda cuneata* f. *digitata* Barton 1901: 16, pl. 2, fig. 9 (Indonesia); Yamada 1941: 111, fig. 4.

Fig. 29

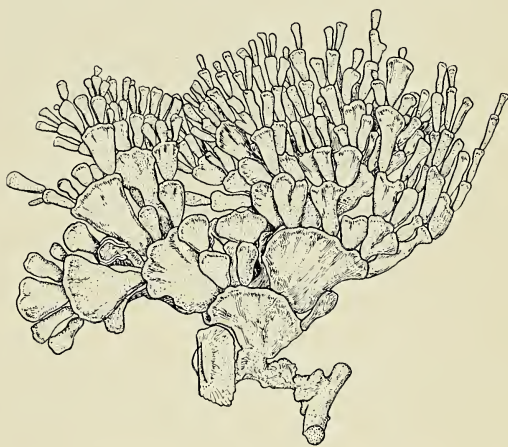


FIG. 29. *Halimeda cuneata* f. *digitata*: Habit of a plant,  $\times 0.55$  (redrawn from Yamada).

KWAJALEIN ATOLL: D. 12620, Sta. 2. Identical with the illustration of the type.

*Halimeda stuposa* Taylor 1950: 90, pl. 43, fig. 1, pl. 49, pl. 50, fig. 2 (Naen Island, Rongelap Atoll, Marshall Islands)

KWAJALEIN ATOLL: D. 12621, Sta. 2.

*Halimeda opuntia* (L.) Lamouroux 1816: 308; Taylor 1950: 80, pl. 39, fig. 1; Dawson 1954: 395, fig. 12. *Corallina opuntia* Linnaeus 1758: 805, in part (Mediterranean Sea)



KWAJALEIN ATOLL: D. 12619, Sta. 2.

JALUIT ATOLL: D. 13099, Sta. 13. An abundant form making large clumps in depths of 5 meters or more, but with quite delicate segments. D. 13112, Sta. 18. A coarser, distinctly ribbed form near what Taylor calls f. *hederacea*. D. 13124, Sta. 19. A form somewhat intermediate between f. *hederacea* and f. *minima*.

**Halimeda gracilis** Harvey, ex. J. G. Agardh 1887: 82 (Ceylon); Taylor 1950: 83, pl. 42

ARNO ATOLL: H. 9525x, H. 9545, Sta. 24. These specimens from the reef drop-off at depths of about 6 meters seem to be nearly identical with the forma *elegans* Yamada (1944b: 28, pl. 3) described from Palao, Caroline Islands. In 1941, previous to the 1944 validation with Latin, he gave a better figure, number 11 on page 117, together with a Japanese diagnosis.

**Halimeda taenicola** Taylor 1950: 86, pl. 46, fig. 1 (Rongerik Atoll, Marshall Islands)

JALUIT ATOLL: D. 13111, Sta. 18.

**Neomeris mucosa** Howe 1909: 84, pl. 1, fig. 5, pl. 5, figs. 1-14 (Bahamas Islands); Yamada and Tanaka 1938: 59, fig. 3

Fig. 30c

ARNO ATOLL: H. 9474, Sta. 28. This single clump of nine axes is in good habit agreement with Howe's photograph of the liquid-pre-

served type and with Yamada and Tanaka's fine illustration of a far western Pacific specimen. The sporangia are like that figured by Koster (1937) and reproduced here. The excessively mucous character of the plants together with the distinctive difference in the peduncle of the sporangia set this species apart from the closely related *N. bilimbata*. The plant is found in the Bahamas growing together with *Neomeris annulata*, as it also is in the Ryukyu Archipelago.

**Neomeris bilimbata** Koster 1937: 221, pl. 15, figs. 1, 4, 5 (Itu-Aba, South China Sea)  
Fig. 30a, b

KWAJALEIN ATOLL: D. 12549, Sta. 1. This material, with which a few examples of *Neomeris annulata* are mixed, agrees in detail with the plant described by Koster. The distinctive differences between the sporangia of this species and of *N. vanbosseae* and *N. mucosa* are shown in her illustrations reproduced here. It would seem that the plants attributed by Taylor (1950) to *N. vanbosseae* may be of this species. He says they "were rather smaller in stature than those described by Howe and likewise differed slightly in many structural details."

JALUIT ATOLL: D. 13100, Sta. 18.

**Neomeris annulata** Dickie 1874: 198 (Mauritius); Egerod 1952: 400, pl. 40, text fig. 21a-l, 22a, c; Dawson 1954: 396, fig. 13e

KWAJALEIN ATOLL: D. 12549a, Sta. 1; D. 12679, Sta. 5.

MAJURO ATOLL: D. 12780, Sta. 11.

**Acetabularia exigua** Solms-Laubach 1895: 28, pl. 2, figs. 1, 4 ("Tropical eastern Asia, Macassar, Celebes")

Fig. 31

KWAJALEIN ATOLL: D. 12644, Sta. 2. This material is rather variable in ray number and shape, but is in satisfactory agreement with this species.

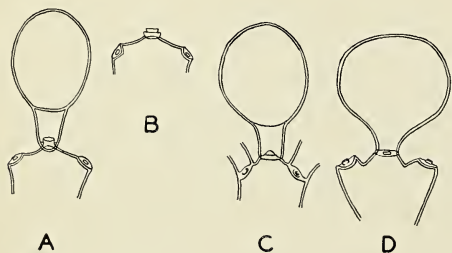


FIG. 30. a, b, *Neomeris bilimbata*: a, A sporangium; b, upper part of a primary branch from which the sporangium has fallen. c, *Neomeris mucosa*: A sporangium. d, *Neomeris vanbosseae*: A sporangium (all figures  $\times 150$ , redrawn from Koster).



FIG. 31. *Acetabularia exigua*: Habit of a plant of D. 12644,  $\times 10$ .

ARNO ATOLL: H. 9238a, Sta. 24. A few individuals growing with more numerous *A. moebii*.

*Acetabularia moebii* Solms-Laubach 1895: 30, pl., 4, fig. 1 (Mauritius); Dawson 1954: 397, fig. 13j

KWAJALEIN ATOLL: D. 12642, Sta. 2.

MAJURO ATOLL: A single individual examined but no specimen made.

JALUIT ATOLL: D. 13008, Sta. 12.

ARNO ATOLL: H. 9232, H. 9238, Sta. 24.

*Ectocarpus indicus* Sonder, in Zollinger 1854: 3 (Indonesia); Weber van Bosse 1913: 129, fig. 34; Børgesen 1941: 16, figs. 6–7; Taylor 1950: 95; 6–7. *E. duchassaigianus* Grunow 1867: 45, pl. 4, figs. a, b, c

Fig. 32

KWAJALEIN ATOLL: D. 12630, D. 12637, Sta. 2. This material is fertile and well developed. The irregular branching seems to be a criterion for distinguishing this plant from *E. mitchellae* in which the plurilocular sporangia are often similar. Vickers and Shaw's (1908) illustration of *E. duchassaigianus* (= *E. indicus*) shows this branching distinction well when compared with their figure of *E. guadeloupensis* (= *E. mitchellae*).

*Ectocarpus breviarticulatus* J. Agardh 1847: 7 (Pacific southern Mexico); Dawson 1954: 398, fig. 14, a, b

MAJURO ATOLL: D. 12773, Sta. 10.

JALUIT ATOLL: D. 13089, Sta. 16.

*Ectocarpus mitchellae* Harvey 1852: 142, pl. 12G (Massachusetts, U. S. A.); Taylor 1950: 95; Dawson 1954: 400, fig. 14 c, d

MAJURO ATOLL: D. 12741, Sta. 7. Note the difference in branching from *E. indicus* as mentioned above.

*Ralfsia expansa* J. Agardh 1847: 7 (Vera Cruz, Mexico); Børgesen 1914: 189, figs. 146–148; Weber van Bosse 1913: 146, fig. 45

Fig. 33

KWAJALEIN ATOLL: D. 12681, Sta. 5. Although sterile, this material agrees structurally with the figures and descriptions cited above. The bilateral condition is prominent when specimens are cut in certain planes. The identification is tentative.

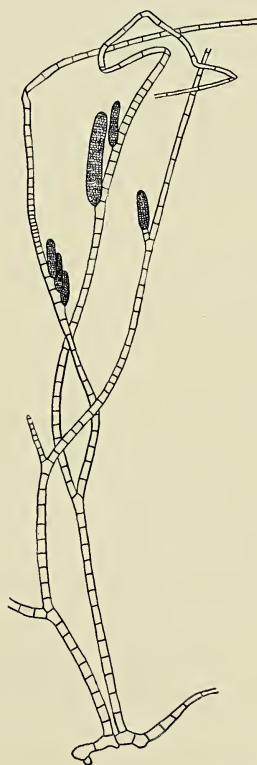


FIG. 32. *Ectocarpus indicus*: Habit of part of plant of Sonder's type collection,  $\times 24$  (redrawn from Weber van Bosse).



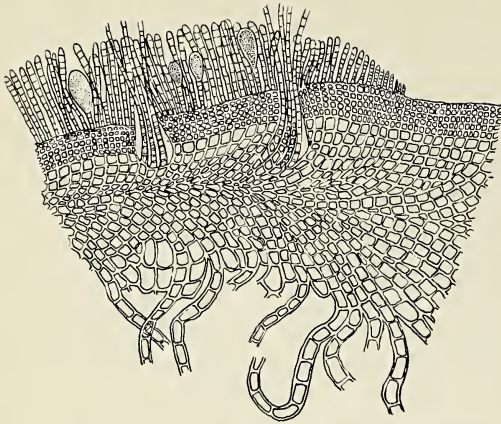


FIG. 33. *Ralfsia expansa*: Part of a transection of a fertile thallus,  $\times 58$  (redrawn from Weber van Bosse).

*Sphacelaria tribuloides* Meneghini 1840: 2, No. 6 (Dalmatia); Dawson 1954: 400, fig. 14i, j

KWAJALEIN ATOLL: D. 12577, D. 12588, Sta. 1; D. 12643, Sta. 3.

*Sphacelaria furcigera* Kützinger 1855, Tab. Phyc. 5, pl. 90, fig. 2 (Karak Island, Persian Gulf); Dawson 1954: 400, fig. 14h

KWAJALEIN ATOLL: D. 12554a, Sta. 1, epiphytic on *Udotea*.

JALUIT ATOLL: D. 13044b, Sta. 13; D. 13172b, Sta. 23.

*Pocockiella variegata* (Lamx.) Papenfuss 1943: 467, figs. 1-14; Taylor 1950: 97; Dawson 1954: 400, fig. 14k. *Dictyota variegata* Lamouroux 1809c: 331 (Antilles)

JALUIT ATOLL: D. 13000, Sta. 12.

ARNO ATOLL: H. 9281a, Sta. 24; H. 9340b, Sta. 26; H. 9367, Sta. 25.

*Pocockiella papenfussii* Taylor 1950: 98, pl. 54, fig. 2 (Bikini Atoll, Marshall Islands)

ARNO ATOLL: H. 9267, H. 9284, Sta. 24. These include well-developed plants to 350  $\mu$  thick or more.

*Padina commersonii* Bory 1828: 114 (Ile de France); Taylor 1950: 100, pl. 54, fig. 1; Dawson 1954: 401, fig. 17

KWAJALEIN ATOLL: D. 12555, Sta. 1, young plants just out of the *Vaughaniella* stage.

MAJURO ATOLL: D. 12713, lagoon shore, Dalap Island; D. 12792, Sta. 11.

JALUIT ATOLL: D. 13033, sandy bottom of small boat landing at Jabor.

*Dictyopteris repens* (Okamura) Børgesen 1924: 265, fig. 13. *Haliseris repens* Okamura 1916: 8, pl. 1, figs. 7-18 (Truk, Caroline Islands)

Fig. 34

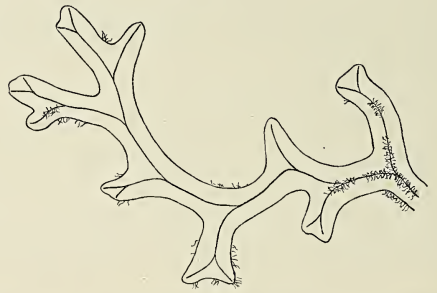


FIG. 34. *Dictyopteris repens*: Part of a plant of D. 13036 as seen from the under side showing rhizoids along the midrib and the margins,  $\times 2.25$ .

JALUIT ATOLL: D. 13036, Sta. 13; D. 13147, Sta. 20.

ARNO ATOLL: H. 9260a, H. 9265, Sta. 24; H. 9581d, H. 9592c, Sta. 25.

*Turbinaria trialata* (J. Agardh) Kützinger 1860, Tab. Phyc. 10: pl. 67, fig. 2; Yendo 1907: 43. *Turbinaria vulgaris* var. *trialata* J. Agardh 1848: 268 (tropical western Atlantic).

JALUIT ATOLL: D. 13062, Sta. 14.

*Turbinaria ornata* (Turn.) J. Agardh 1848: 266; Taylor 1950: 101, pl. 54, fig. 2, pl. 55, fig. 2; Dawson 1954: 405, fig. 21. *Fucus turbinatus* var. *ornatus* Turner 1808: 50, pl. 24, figs. c, d (type locality unknown)

KWAJALEIN ATOLL: D. 12654, Sta. 4.



FIG. 35. *Galaxaura fasciculata*: Habit photo of a plant of D. 13098,  $\times 1$ .

JALUIT ATOLL: D. 13125, Sta. 19.

ARNO ATOLL: H. 9470, Sta. 24.

*Erythrotrichia carnea* (Dillwyn) J. Agardh 1883: 15; Tanaka 1952: 14, fig. 7B-E; Taylor 1950: 117. *Conferva carnea* Dillwyn 1805: 54, pl. 84 (Wales)

KWAJALEIN ATOLL: D. 12558b, Sta. 1. These represent a quite slender form best referred to Tanaka's *f. tenuis*.

JALUIT ATOLL: D. 13073, Sta. 15.

ARNO ATOLL: H. 9205, H. 9534c, Sta. 24.

*Falkenbergia hillebrandii* (Bornet) Falkenberg = sporophyte generation of *Asparagopsis taxiformis* (Delile) Collins and Hervey; Feldmann and Feldmann 1942: 89; Dawson 1954: 414, fig. 251. *Polysiphonia*

*hillebrandii* Bornet, in Ardissonne 1883: 376 (Italy)

KWAJALEIN ATOLL: D. 12564, D. 12591, Sta. 1.

JALUIT ATOLL: D. 13084, Sta. 16 (a rather coarse form).

ARNO ATOLL: H. 9358, H. 9598, Sta. 25.

*Galaxaura fasciculata* Kjellman 1900: 53, pl. 5, figs. 1-9, pl. 20, fig. 14 (Celebes Islands). Chou 1945: 44, pl. 2, fig. 2, pl. 8, fig. 1

Fig. 35

JALUIT ATOLL: D. 13098, Sta. 15.

*Galaxaura acuminata* Kjellman, in Butters 1911: 180 (Hawaii); Svedelius 1953: 63,



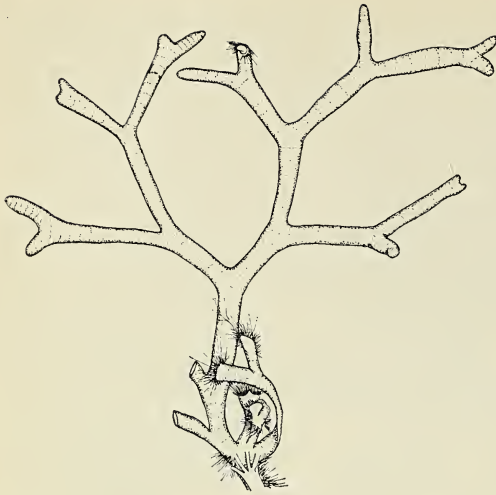


FIG. 36. *Galaxaura acuminata*: Habit of a small part of a plant of D. 13092, 1.5.

figs. 53–55, 57–60. Chou 1945: 51, pl. 5, figs. 13–19, pl. 9, fig. 1 (as *G. apiculata*)  
Fig. 36

JALUIT ATOLL: D. 13092, Sta. 17. This abundant material is in complete agreement with Svedelius' interpretation of this plant.

*Galaxaura filamentosa* Chou 1945: 39, pl. 1, figs. 1–6, pl. 6, fig. 1 (Revillagigedo Archipelago, Mexico); Dawson 1954: 419, fig. 30a

KWAJALEIN ATOLL: D. 12600, Sta. 2.

JALUIT ATOLL: D. 13082, Sta. 16; D. 13131, Sta. 19.

ARNO ATOLL: H. 9273, Sta. 24, a single small plant.

*Actinotrichia fragilis* (Forsk.) Børgesen 1932: 6, pl. 1, fig. 4; Dawson 1954: 416, fig. 28b. *Fucus fragilis* Forskål 1775: 190 (Red Sea)

JALUIT ATOLL: D. 13039, Sta. 13 (abundant at 5 meters and below); D. 13095, Sta. 17.

*Gelidium pusillum* (Stackh.) Le Jolis 1864: 139; Dawson 1954: 420, fig. 31a–c. *Fucus pusillus* Stackhouse 1801: 17, pl. 6 (England)

KWAJALEIN ATOLL: D. 12576, Sta. 1.

JALUIT ATOLL: D. 13038a, D. 13055 (creeping on *Amphiroa*), Sta. 13; D. 13078, Sta. 15.

ARNO ATOLL: H. 9224, H. 9230, Sta. 24.

Several different forms are present of which some may be referred to var. *conchicola* Piccone and Grunow and others to var. *minusculum* Weber van Bosse.

*Gelidiella adnata* Dawson 1954: 422, fig. 33f (Nhatrang, Việt Nam)

ARNO ATOLL: H. 9213, H. 9246, H. 9467a, Sta. 24. These materials are apparently sterile but vegetatively are in agreement with the type and also with similar sterile specimens from Isla San Benedicto, Mexico. The determination is tentative awaiting comparison of reproduction with such similar small species as *G. stichidiospora* Dawson.

*Gelidiella tenuissima* Feldmann and Hamel 1936: 102 (Mediterranean France); Dawson 1954: 422, fig. 33e

MAJURO ATOLL: D. 12706, Sta. 6.

JALUIT ATOLL: D. 13153b, Sta. 21.

ARNO ATOLL: H. 9634b, H. 9640, Sta. 24.

*Gelidiopsis intricata* (Ag.) Vickers 1905: 61; Dawson 1954: 423, fig. 34a–d. *Sphaerococcus intricatus* C. Agardh 1822: 333 (Ravak Island)

MAJURO ATOLL: D. 12686, Sta. 6; D. 12793, Sta. 11.

JALUIT ATOLL: D. 13035 (sterile), D. 13040a (♂), Sta. 13.

ARNO ATOLL: H. 9634, Sta. 24, probably this, but very dwarfish.

*Gelidopsis repens* (Kützinger) Schmitz 1895: 148; Weber van Bosse 1928: 425; Okamura 1931: 113. *Gelidium repens* Kützinger 1868, Tab. Phyc. 18: 21, pl. 60a, b (New Caledonia)

Fig. 37

ARNO ATOLL: H. 9628, Sta. 24; H. 9346, Sta. 26.

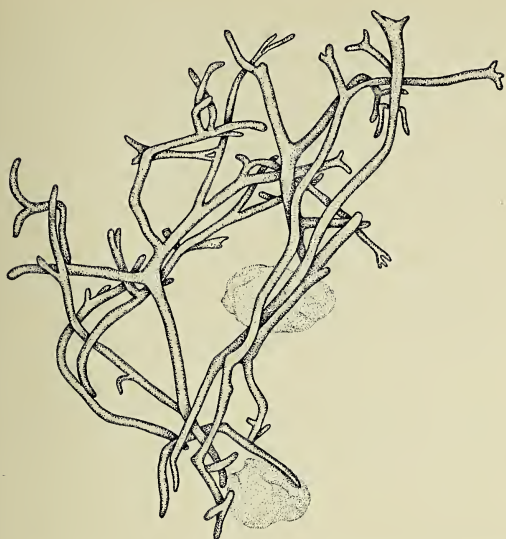


FIG. 37. *Gelidiopsis repens*: Habit of part of a plant of H. 9628 with attached sand grains,  $\times 2$ .

**Wurdemannia miniata** (Lmk. and DC) Feldmann and Hamel 1934: 544, figs. 9–11; Dawson 1954: 424, fig. 35. *Fucus miniatus* Lamarck and De Candolle 1815: 6 (Mediterranean France)

KWAJALEIN ATOLL: D. 12578, Sta. 1.

MAJURO ATOLL: D. 12749a, Sta. 8.

JALUIT ATOLL: D. 13172e, Sta. 23.

ARNO ATOLL: H. 9375, Sta. 27 (typical material about 140  $\mu$  in diameter).

**Hildenbrandia prototypus** Nardo 1834: 675 (Adriatic Sea); Dawson 1954: 424, fig. 36a, b

JALUIT ATOLL: D. 13158, Sta. 22 (growing on broken glass).

**Peyssonelia conchicola** Piccone and Grunow, in Piccone 1884b: 317, pl. 7, figs. 5–8 (Massaua, Red Sea), Dawson 1953: 105, pl. 11, figs. 12–13

Fig. 38

KWAJALEIN ATOLL: D. 12682, Sta. 5. This material is in excellent correspondence with Dawson's interpretation of Mexican specimens.

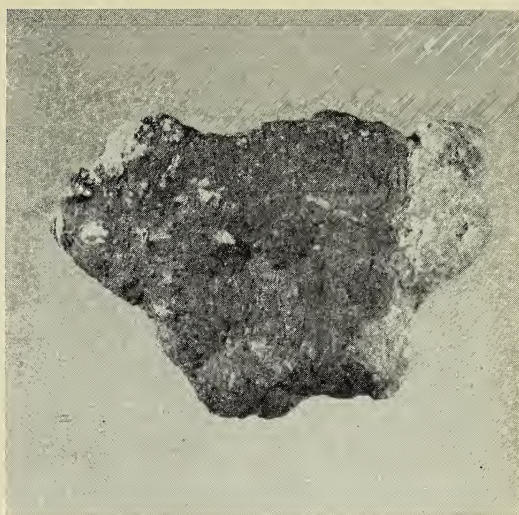


FIG. 38. *Peyssonelia conchicola*: Habit of a plant of D. 12682 growing on a coral rock fragment,  $\times 1$ .

JALUIT ATOLL: D. 13080, Sta. 15; D. 13091, Sta. 17.

**Peyssonelia rubra** var. **orientalis** Weber van Bosse 1921: 270, figs. 86–89 (Indonesia); Taylor 1950: 121; Dawson 1953: 104, pl. 10, figs. 8, 9; Dawson 1954: 424, fig. 36c

KWAJALEIN ATOLL: D. 12614, D. 12622, Sta. 2; D. 12668, Sta. 3.

JALUIT ATOLL: D. 13006, Sta. 12; D. 13079, Sta. 15.

ARNO ATOLL: H. 9440, Sta. 24.

**Cruoriella dubyi** (Crouan and Crouan) Schmitz 1889: 20; Dawson 1953: 111, pl. 7, figs. 2–3. *Peyssonelia dubyi* Crouan and Crouan 1844: 367, pl. 11, figs. 6–10 (Atlantic France)

Fig. 39

KWAJALEIN ATOLL: D. 12584, D. 12585a, Sta. 1; D. 12682a, Sta. 5.

**Heteroderma minutula** Foslie 1904: 8 (southern Norway); Suneson 1943: 27, figs. 14, 15

Fig. 40



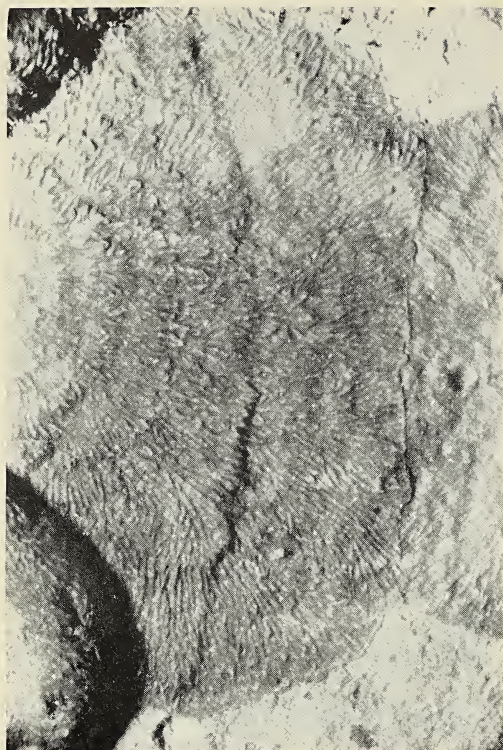


FIG. 39. *Cruoriella dubyi*: Habit of a well-developed thallus growing on a shell, showing the characteristic anastomosing ridges on the dry upper surface,  $\times 6.5$ .

KWAJALEIN ATOLL: D. 12557a, Sta. 1, on the surface of *Dictyosphaeria intermedia* var. *solida*. This material agrees well in size, the presence of cortical (cap) cells, size of conceptacles, etc., with this species which, unlike similar *H. lejolisii*, commonly occurs as an epiphyte on algae. In some of the thalli the organization of the cell rows is rather loose, approaching the condition in f. *lacunosa* Fosl. The conceptacles are similar in size to those of *H. subtilissima*, being less than  $100\ \mu$  in diameter. The distribution of this small plant is little known, and although it may be nearly cosmopolitan, has not heretofore been recorded in the Pacific.

ARNO ATOLL: H. 9390x, Sta. 24, growing on *Siphonocladus rigidus*, is very much like f. *lacunosa* as illustrated by Suneson except that the primary cell rows are composed of cells mostly twice as long as wide or more. Re-

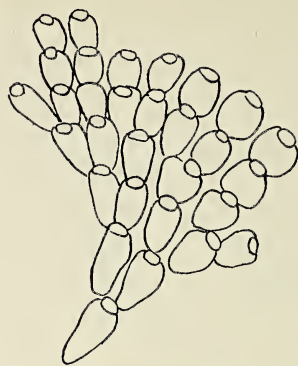


FIG. 40. *Heteroderma minutula*: A small part of a vegetative thallus (D. 12557a) showing the small cap cells and the absence of heterocysts,  $\times 600$ .

production was not seen, but the absence of heterocysts and the presence of the cap cells points to relationship here.

***Heteroderma subtilissima*** (Foslie) Foslie 1909: 56. *Melobesia subtilissima* Foslie, in Weber van Bosse and Foslie 1904: 55 (New Guinea)

Fig. 41

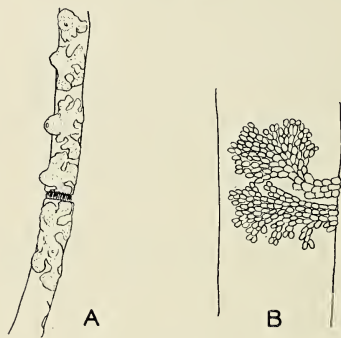


FIG. 41. *Heteroderma subtilissima*: a, Habit of fertile plants on a piece of *Jania* (D. 12558a),  $\times 25$ ; b, detail of the same showing arrangement of cells and absence of cap cells and heterocysts,  $\times 85$ .

KWAJALEIN ATOLL: D. 12558a, Sta. 1, epiphytic on *Jania decussato-dichotoma*. These plants are exceedingly small and inconspicuous. Conceptacles are quite frequent, however, and aid in their recognition. Most of the conceptacles are somewhat larger than the  $60\ \mu$  indicated by Foslie for the type, usually

ranging from 60 to 90  $\mu$  in outside diameter at the base, occasionally to 100  $\mu$ . No heterocysts are present nor are any cortical (cap) cells apparent in the material examined. This is in agreement with Foslie's original account of the species and marks a distinction from *H. minutula* in which the cortical cells are abundant.

**Fosliella farinosa** (Lamx.) Howe 1920: 587; Dawson 1954: 425, fig. 37c. *Melobesia farinosa* Lamouroux 1816: 315, pl. 12, fig. 3 (Europe)

JALUIT ATOLL: D. 13102, Sta. 18, on *Microdictyon*. Heterocysts are abundant and conspicuous, but inasmuch as conceptacles were not found for measurement, the distinction from closely related *F. paschalis* (Lemoine) Setch. and Gard. cannot be made here.

ARNO ATOLL: H. 9581e, Sta. 25, sterile plants on *Laurencia*.

**Lithoporella pacifica** (Heydr.) Foslie 1909: 59; Dawson 1954: 428, fig. 40b. *Melobesia pacifica* Heydrich 1901: 529 (Hawaii)

JALUIT ATOLL: D. 13058, Sta. 13; D. 13118, Sta. 19.

**Jania micrarthrodia** Lamouroux 1816: 271, pl. 9, fig. 5a, b (Australia). Taylor 1950: 134 (as *J. antennina* Kütz. prox.)

Fig. 42

ARNO ATOLL: H. 9371a, Sta. 24; H. 9390c, Sta. 26. These specimens are apparently like those Taylor reported from Eniwetok as *Jania antennina*. Womersley (1950) has recently reiterated the synonymy of *J. micrarthrodia* which includes both *J. antennina* Kütz. and *J. tenuissima* Sonder. In the Australian region the species seems generally to be epiphytic on large fleshy algae. The present specimens grew on branched lithothamnioids on the seaward reef ridge.

**Jania capillacea** Harvey 1853: 84 (Bahia Honda, Florida); Dawson 1954: 432, fig. 41a, b; Dawson 1953: 116, pl. 9, fig. 1; Taylor 1950: 133

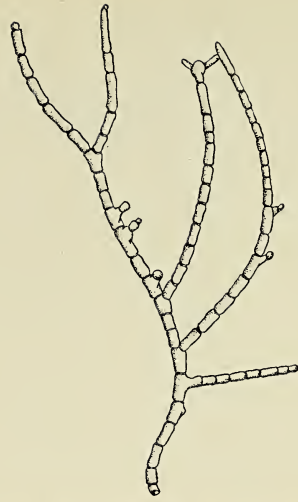


FIG. 42. *Jania micrarthrodia*: Branching and segmentation of part of H. 9371a,  $\times 6$ .

KWAJALEIN ATOLL: D. 12559a, Sta. 1 (in part consisting of exceedingly slender plants ranging between 38 and 70  $\mu$  in diameter); D. 12604a, D. 12639, Sta. 2.

MAJURO ATOLL: D. 12776, Sta. 10.

JALUIT ATOLL: D. 13147a, Sta. 20; D. 13150a, Sta. 21.

ARNO ATOLL: H. 9203, H. 9274, Sta. 24.

**Jania tenella** Kützling 1858, Tab. Phyc. 8: 41, pl. 85, fig. 2; Dawson 1953: 120, pl. 9, fig. 3

Fig. 43

KWAJALEIN ATOLL: D. 12673, Sta. 5.

JALUIT ATOLL: D. 13013, Sta. 12; D. 13148, Sta. 14 (characteristic material with conceptacles).

**Jania decussato-dichotoma** (Yendo) 1905: 37. *Corallina decussato-dichotoma* Yendo 1902: 25, pl. 3, figs. 1-3, pl. 7, figs. 3-4 (southern Japan)

Fig. 44

KWAJALEIN ATOLL: D. 12558, Sta. 1. The segments are mostly 100 to 150  $\mu$  in diameter and are usually well distinguished in the algal turf from the much more slender *J. capillacea*



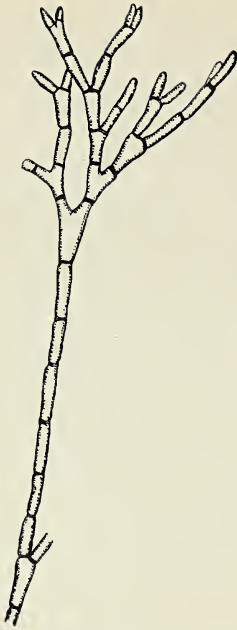


FIG. 43. *Jania tenella*: An isotype fragment from the Kützing collection in the Rijksherbarium, Leiden,  $\times 18$ .

with which it often grows. Undoubtedly some of the plants attributed by Taylor (1950) to *Jania rubens* are referable here.

MAJURO ATOLL: D. 12697, Sta. 6. A very slender form 85 to 115  $\mu$  in diameter.

***Amphiroa taylorii* Dawson (prox.) 1953:** 138, pl. 26, fig. 1 (Pacific Mexico)

MAJURO ATOLL: D. 12770, Sta. 10. This is a slender, sterile form with dizonal genicula. It is much like the type, but a little smaller and more branched. The branches are less crooked than in the type. Constrictions at the genicula are apparent only in dry material; the genicula are about the same diameter as the intergenicula when fresh. This plant is possibly distinct, but too close to *A. taylorii* to justify segregation on the basis of this single collection.

***Amphiroa fragilissima* (L.) Lamouroux** 1816: 298; Dawson 1954: 430, fig. 40g, h. *Corallina fragilissima* Linnaeus 1767: 1305 (Caribbean Sea)

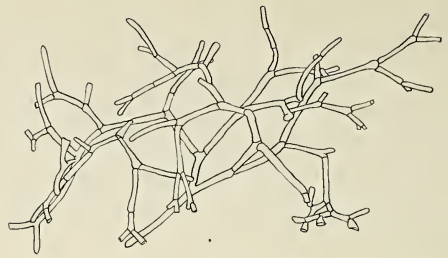


FIG. 44. *Jania decussato-dichotoma*: Part of a plant extracted from a dense clump (D. 12558) to show the decussate branching habit,  $\times 5$ .

JALUIT ATOLL: D. 13043, D. 13051, Sta. 13; D. 13145, Sta. 20. These plants are for the most part representative of a variant of *A. fragilissima* near f. *cyathifera* (Lamk.) Weber van Bosse.

ARNO ATOLL: H. 9677, Sta. 25. Fertile and rather small from about 5 meters depth.

***Amphiroa anastomosans* Weber van Bosse,** in Weber van Bosse and Foslie 1904: 91, pl. 14, figs. 3-4 (Borneo Bank, Indonesia)

Fig. 45

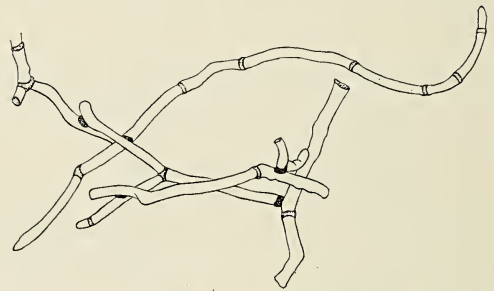


FIG. 45. *Amphiroa anastomosans*: A small part of a clump (H. 9527) showing frequent attachment of branches to each other by adherent discs,  $\times 6$ .

ARNO ATOLL: H. 9527, Sta. 24. This material is somewhat larger and more laxly branched than the type illustrated by Weber van Bosse, but agrees closely in shape, proportions, dichotomous branching of the slightly contorted axes, and especially in the frequent anastomoses throughout the clumps. H. 9592e, Sta. 25.

*Amphiroa foliacea* Lamouroux 1824: 628, pl. 93, figs. 2–3 (Mariannas Islands); Dawson 1954: 430, fig. 40c

JALUIT ATOLL: D. 13038, Sta. 13. This material represents an exceptionally narrow form which agrees best with the East Indian form *erecta* described by Weber van Bosse in 1904.

*Hypnea pannosa* J. Agardh 1847: 14 (Pacific Mexico); Tanaka 1941: 247, fig. 20; Taylor 1945: 277, pl. 71, fig. 2

Fig. 46

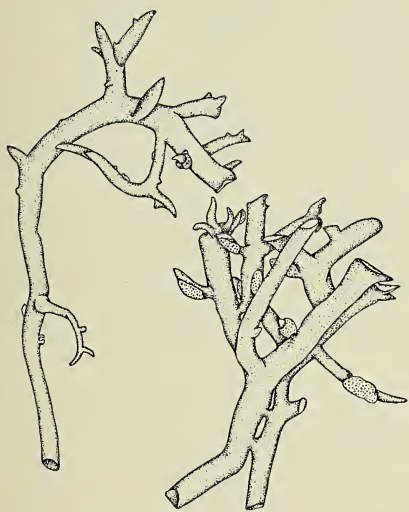


FIG. 46. *Hypnea pannosa*: Portions of two plants of D. 12734 showing tetrasporangial sori,  $\times 5$ .

MAJURO ATOLL: D. 12734, Sta. 7.

JALUIT ATOLL: D. 13005, Sta. 12; D. 13090, Sta. 16.

ARNO ATOLL: H. 9266, H. 9273a, Sta. 24.

The specimens cited above are all smaller in dimensions than the coarser *H. nidulans*, but often have similar saddle-shaped nemathecia when the tetrasporangia are sharply confined to one side of a branch. Most of them are in good agreement with the type which has been seen.

*Hypnea esperi* Bory 1829: 157 (type locality uncertain); Dawson 1954: 436, fig. 46h–j

KWAJALEIN ATOLL: D. 12611, Sta. 2; D. 12664, Sta. 5.

MAJURO ATOLL: D. 12684, Sta. 6.

JALUIT ATOLL: D. 13096, Sta. 17; D. 13117, Sta. 19.

*Champia parvula* (Ag.) Harvey 1853: 76; Dawson 1954: 443, fig. 52c. *Chondria parvula* C. Agardh 1824: 207 (Cadiz, Spain)

MAJURO ATOLL: D. 12684b, D. 12695, Sta. 6.

ARNO ATOLL: H. 9255, Sta. 24.

*Champia vieillardii* Kützinger 1866, Tab. Phyc. 16: 14, pl. 37e, f (New Caledonia); Dawson 1954: 443, figs. 52e, 53

JALUIT ATOLL: D. 13011, Sta. 12. This is but a small fragmentary specimen, but nevertheless a distinctive record. The plant reported from Truk Atoll and illustrated by Okamura (1906: 10, figs. 7–8) as *Champia compressa* is most probably this species.

*Chrysomenia kairnbackii* Grunow, prox.

JALUIT ATOLL: D. 13010a, D. 13025, Sta. 12. Although they are very small, these correspond in habit with *C. kairnbackii* as illustrated by Yamada and Segawa 1953: 111, fig. 4 from Ponape, and clearly are unlike their *C. okamurai*. The few cystocarpic plants are much like Weber van Bosse's figures and description (1928: 469) but with fewer rhizoids below the cystocarp and with no rhizoids in the cavity. Whether these differences are significant must await the collection of more ample material and comparison with both Siboga specimens and Grunow's type.

*Coelarthrum boergesenii* Weber van Bosse 1928: 473, figs. 207–208 (Borneo Bank)  
Fig. 47

ARNO ATOLL: H. 9623, Sta. 24. Only a single small example of this species is present, but it is in complete agreement in size, shape, structure and anastomoses of the branches with the Weber van Bosse plant. Our specimen came from the under surface of an



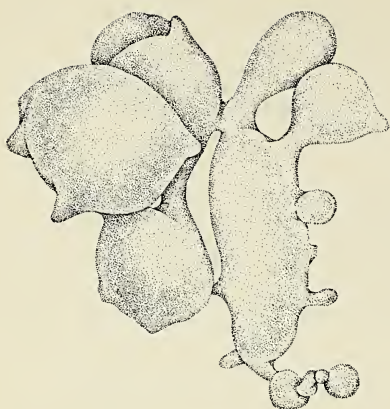


FIG. 47. *Coelarthrum boergesenii*: The entire specimen under H. 9623,  $\times 6$ .

overhanging coral on the reef and agrees with her forma *minima* even as to having the "algue parasite filamenteus verte parmi les cellules de ses articles ou vésicules" as mentioned in the description of the type.

***Botryocladia skottsbergii*** (Børgesen) Levring 1941: 645; G. Feldmann 1945: 55. *Chrysomenia skottsbergii* Børgesen 1924: 307, figs. 49–50 (Easter Island). *Botryocladia kuckuckii* (Weber van Bosse) Yamada and Tanaka 1938: 466, figs. 8–9; Taylor 1950: 135

Fig. 48

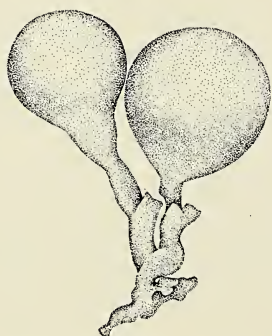


FIG. 48. *Botryocladia skottsbergii*: A small example from H. 9364,  $\times 5$ .

ARNO ATOLL: H. 9384, Sta. 26; H. 9685b, Sta. 25.

***Rhodymenia anastomosans*** Weber van Bosse 1926: 150, fig. 39 (Kei Islands, Doe-Roa, at 20 meters)

Fig. 49



FIG. 49. *Rhodymenia anastomosans*: A cystocarpic plant of D. 13120 showing the repent habit and "anastomosing" branches,  $\times 2$ .

JALUIT ATOLL: D. 13120, Sta. 19. Both antheridial and carposporic specimens are present and show good agreement with this little known species heretofore reported but once.

***Lomentaria hakodatensis*** Yendo 1920: 6 (Japan). *Lomentaria sinensis* Howe 1924: 139, pl. 1, fig. 1

Fig. 50

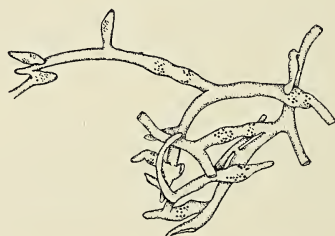


FIG. 50. *Lomentaria hakodatensis*: Part of a clumping tetrasporic example of D. 12616,  $\times 5$ .

KWAJALEIN ATOLL: D. 12616, Sta. 2. This tetrasporic material is in excellent agreement with this species as known from China, Japan, and from Pacific Mexico.

JALUIT ATOLL: D. 13015, Sta. 12; D. 13165, Sta. 23. All tetrasporic.

**Antithamnion lherminieri** (Crouan and Crouan) Nasr 1941: 66, figs. 9–10. *Callithamnion lherminieri* Crouan and Crouan, in Mazé and Schramm 1870–77: 144. *Antithamnion antillanum* Børgesen 1915–20: 226, figs. 213–216

Fig. 51

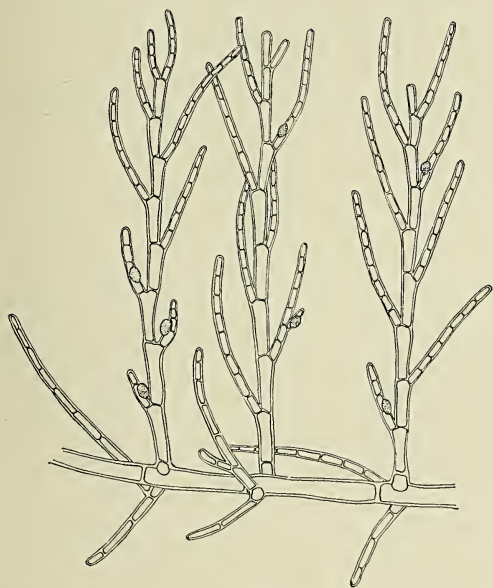


FIG. 51. *Antithamnion lherminieri*: Part of a plant of D. 13044a,  $\times 100$ .

JALUIT ATOLL: D. 13044a, D. 13050b, Sta. 13; D. 13164, Sta. 23.

**Ceramium gracillimum** var. *byssoides* (Harv.) G. Mazoyer 1938: 323; Dawson 1954: 448, fig. 55e, f. *Ceramium byssoides* Harvey 1853: 218 (Key West, Florida); Taylor 1950: 138

KWAJALEIN ATOLL: D. 12554b, D. 12581, Sta. 1; D. 12599, Sta. 2; D. 12672, Sta. 5.

MAJURO ATOLL: D. 12720a, lagoon side, Enierippu Island; D. 12761, Sta. 9; D. 12791, Sta. 11.

JALUIT ATOLL: D. 13019, D. 13026, Sta. 12; D. 13049, Sta. 13; D. 13113, Sta. 19.

ARNO ATOLL: H. 9581f, Sta. 25.

The specimens of these many collections are variable. Some of them, such as D. 12599,

have abundant gland cells and solitary sporangia which, standing alone, would distinguish them from the Pacific Mexican *Ceramium masonii* Dawson (1950b: 126, pl. 2, figs. 11–12). Others, however, such as D. 12672, show few or no gland cells and have whorled, involucrate sporangia as in *C. masonii*, suggesting that only a single, widespread, variable species is involved.

**Ceramium mazatlanense** Dawson 1950b: 130, pl. 2, figs. 14–15 (Mazatlán, Mexico); Dawson 1954: 448, fig. 55g–j

JALUIT ATOLL: D. 13027, Sta. 12. Agrees excellently with the tetrasporic type.

ARNO ATOLL: H. 9165a, H. 9627a, Sta. 24; H. 9588, Sta. 25.

**Ceramium fimbriatum** Setchell and Gardner 1924: 777, pl. 26, figs. 43, 44 (Gulf of California, Mexico); Dawson 1954: 446, fig. 55a

KWAJALEIN ATOLL: D. 12577, Sta. 1.

JALUIT ATOLL: D. 13110, Sta. 18. Only a small but distinctive bit noted.

**Ceramium camouii** Dawson 1944: 319, pl. 51, figs. 2–3 (Turner's Island, Gulf of California, Mexico); Dawson 1950b: 129

Fig. 52



FIG. 52. *Ceramium camouii*: A small part of a tetrasporic axis of H. 9527a, showing the tumid nodal whorls,  $\times 200$ .



ARNO ATOLL: H. 9527a, Sta. 24. A few branches of the specimens of this collection bear tetrasporangia in the characteristic strongly tumid whorls unlike the solitary ones of *C. serpens*. Vegetatively *C. camouii* and *C. serpens* are similar and may not readily be distinguished unless found in tetrasporic condition. This species has been reported from both tropical and subtropical areas on the coast of Pacific Mexico, but not heretofore in the central Pacific.

***Ceramium serpens*** Setchell and Gardner 1924: 775, pl. 27, fig. 58 (Gulf of California, Mexico)

Fig. 53

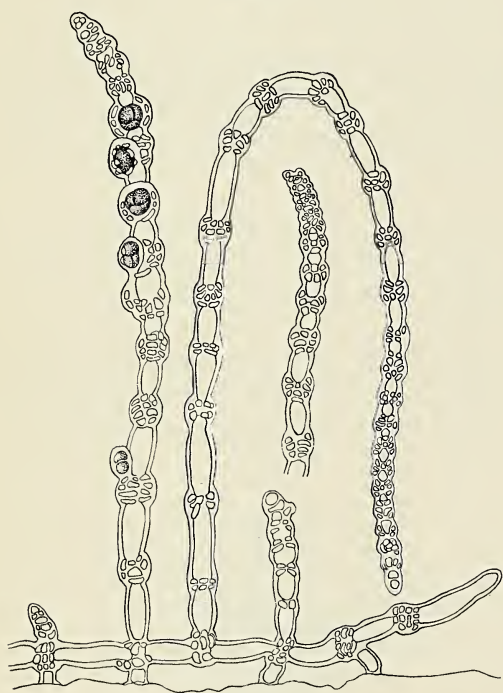


FIG. 53. *Ceramium serpens*: Part of a tetrasporic plant of the type collection,  $\times 125$  (redrawn from Setchell and Gardner).

MAJURO ATOLL: D. 12717a, lagoon side of Enierippu Island. This tetrasporic material is identical with the Mexican type.

JALUIT ATOLL: D. 13044, Sta. 13; D. 13074, Sta. 15.

ARNO ATOLL: H. 9246a, H. 9448a, Sta. 24.

***Ceramium clarionense*** Setchell and Gardner 1930: 170, pl. 7, figs. 25–27 (Isla Clarión, Revillagigedo Archipelago, Mexico); Dawson 1954: 448, fig. 55k

MAJURO ATOLL: D. 12722, lagoon shore of Enierippu Island. Very well-developed material. D. 12782, D. 12791a, Sta. 11.

***Ceramium huysmansii*** Weber van Bosse 1923: 322, fig. 115a, b (Indonesia); Dawson 1954: 446, fig. 55d

ARNO ATOLL: H. 9165, H. 9467, Sta. 24. Tetrasporic material among these specimens is manifestly like the Indonesian and Vietnamese plants cited above. Børgesen has reported this species from Mauritius under the name *Ceramiella*. It also seems clearly to be the same as the plant described and figured by Setchell (1926: 104, pl. 21, fig. 1–2) as *Bostrychia exigua*.

***Centroceras minutum*** Yamada 1944a: 42 (Ant Atoll, Ponape, Caroline Islands)

Fig. 54

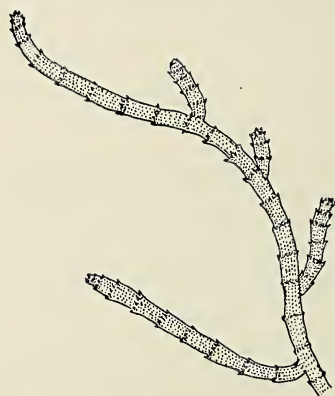


FIG. 54. *Centroceras minutum*: Habit of part of a creeping plant of H. 9611,  $\times 10$ .

ARNO ATOLL: H. 9611, Sta. 29. This material of a small, creeping, irregularly branched, non-forcipate *Centroceras* agrees excellently with Yamada's description. Although it would

appear hazardous to recognize another *Centroceras* with a number of characters in common with the widespread and variable *C. clavulatum*, the habit and general lack of dichotomous branching do seem to distinguish this small plant. H. 9630, Sta. 24, represents quite abundant material creeping on *Valonia aegagropila* in company with *C. apiculatum*. Note that dichotomous branching is not infrequent in certain well-developed free branches.

***Centroceras apiculatum*** Yamada 1944a: 42  
(Ant Atoll, Caroline Islands)

Fig. 55

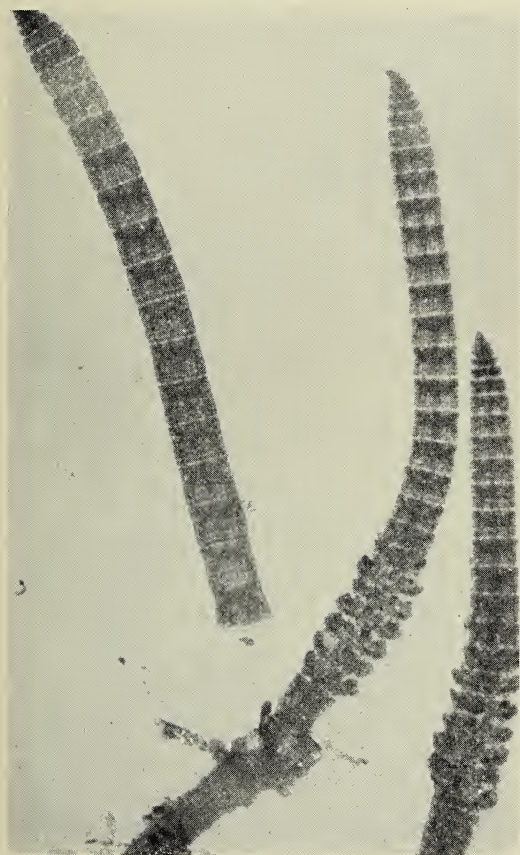


FIG. 55. *Centroceras apiculatum*: Terminal portions of a sterile axis and two tetrasporangial axes of H. 9543a,  $\times 68$ .

ARNO ATOLL: H. 9284a, H. 9527b, H. 9543a, H. 9630b, Sta. 24. This material, part

of which is tetrasporic, agrees in all respects with Yamada's description.

***Centroceras clavulatum*** (Ag.) Montagne, in Durieu 1846: 140; Taylor 1950: 139; Dawson 1954: 446, fig. 54b. *Ceramium clavulatum* C. Agardh, in Kunth 1822: 2 (Peru)

KWAJALEIN ATOLL: D. 12578a, Sta. 1. This material is mostly of f. *inerme* (Kütz.) Piccone. D. 12604, D. 12636, Sta. 2; D. 12650, Sta. 3.

MAJURO ATOLL: D. 12693, Sta. 6; D. 12737, Sta. 7. This is f. *inerme* (Kütz.) Piccone. D. 12749, Sta. 8.

JALUIT ATOLL: D. 13034a, D. 13053, Sta. 13.

***Crouania minutissima*** Yamada 1944a: 41  
(Ant Atoll, near Ponape, Caroline Islands)

Fig. 56



FIG. 56. *Crouania minutissima*: Habit of a plant from H. 9585,  $\times 20$ .

ARNO ATOLL: H. 9585, H. 9594a, Sta. 25. The abundant material of this beautiful little plant agrees excellently with the description given by Yamada of the type from nearby Ponape, except that the primary branchlets appear not to occur in groups of four at "every whorl." In the present specimens there appear often to be only three such primary



branchlets in a whorl. Such variation occurs also in the type species, *C. attenuata*.

**Wrangelia argus** (Mont.) Montagne 1856: 444; Dawson 1954: 444, fig. 54g. *Griffithsia argus* Montagne 1840a: 176, pl. 8, fig. 4 (Canary Islands)

MAJURO ATOLL: D. 12748, Sta. 8; D. 12774, Sta. 10.

ARNO ATOLL: H. 9592f, H. 9598f, H. 9600a, Sta. 25.

**Spyridia filamentosa** (Wulf.) Harvey, in Hooker 1833: 337; Taylor 1950: 139; Dawson 1954: 444, fig. 54i, j. *Fucus filamentosus* Wulfen 1803: 63 (Europe)

KWAJALEIN ATOLL: D. 12608, Sta. 2; D. 12665, Sta. 4.

MAJURO ATOLL: D. 12761a, Sta. 9; D. 12781, Sta. 11.

**Spermothamnion saccorhiza** (Setch. and Gard.) Feldmann-Mazoyer 1942: 16. *Pleonosporium saccorhiza* Setchell and Gardner 1930: 168, pl. 10, fig. 39 (on *Codium*, Isla Guadalupe, Mexico)

Fig. 57

KWAJALEIN ATOLL: D. 12571, Sta. 1; D. 12612, Sta. 2. Both on *Codium*.

**Griffithsia tenuis** C. Agardh 1828: 131 (Venice, Italy); Dawson 1954: 450, fig. 56e

JALUIT ATOLL: D. 13018b, Sta. 12; D. 13034, Sta. 13.

**Griffithsia metcalfii** Tseng 1942: 111, figs. 5-9 (Hainan, China); Dawson 1954: 450, fig. 56 k, l; Abbott 1946: 440, pl. 2, figs. 3-6

KWAJALEIN ATOLL: D. 12610, Sta. 2. This material is tetrasporic and agrees with Abbott's key and figures.

**Martensia fragilis** Harvey 1854: 145 (Ceylon); Svedelius 1908: 11, figs. 8, 10-28, pl. 1, figs. 1-10, pl. 2, figs. 6-10, pls. 3-4; Okamura 1916: 11

Fig. 58

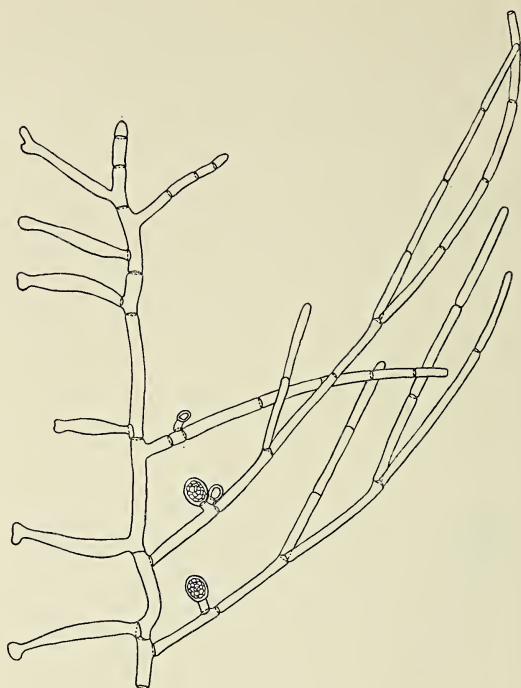


FIG. 57. *Spermothamnion saccorhiza*: Part of a plant of the type collection,  $\times 37.5$  (redrawn from Setchell and Gardner).

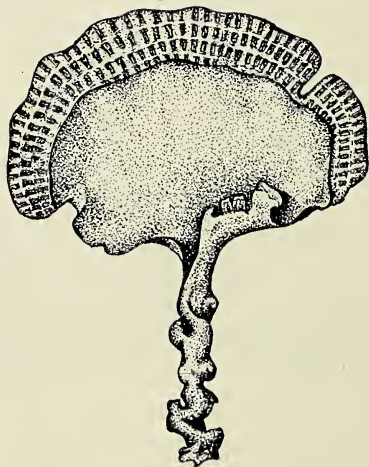


FIG. 58. *Martensia fragilis*: A young male plant showing early development of network,  $\times 4$  (redrawn from Svedelius).

ARNO ATOLL: H. 9059a, Sta. 25. Only a few fragmentary specimens are present, but in size, habit, and structure they appear to agree with this species which Okamura has reported from Truk Atoll.

*Caloglossa adnata* (Zanardini) De Toni 1900: 730; Dawson 1954: 451, fig. 58b. *Delesseria adnata* Zanardini 1872: 141, pl. 5B, figs. 1-3 (Sarawak, Borneo)

JALUIT ATOLL: D. 13084b, Sta. 16.

*Caloglossa leprieurii* (Montagne) J. Agardh 1876: 499; Taylor 1950: 140. *Delesseria leprieurii* Montagne 1840b: 196, pl. 5, fig. 1a-f (French Guiana)

Fig. 59



FIG. 59. *Caloglossa leprieurii* f. *pygmaea*: Habit of a plant of D. 12609a growing on *Valonia*,  $\times 4$ .

KWAJALEIN ATOLL: D. 12609a, Sta. 2. These minute plants on the membrane of *Valonia* correspond with the f. *pygmaea* of Post 1936: 49.

JALUIT ATOLL: D. 13058a, Sta. 13. On the surface of *Lithoporella*.

ARNO ATOLL: H. 9628a, Sta. 24; H. 9489, Sta. 28. These minute plants were growing among blue-green algae on the under side of a flat rock on the lagoon reef. They differ somewhat from those under D. 12609a as figured, in having abundant stoloniferous parts which are very narrow, even subcylindrical in part, and erect parts which are longer and narrower. Because of the great variation known to exist in this widespread species of

both marine and fresh water it seems well to assign the Arno material here.

*Dictyurus purpurascens* Bory, in Belanger and Bory 1846: 170, pl. 15, fig. 2 (Cape Comorin, Indian Ocean); Falkenberg 1901: 675, pl. 17, figs. 10-24; Svedelius and Nygren 1946: 3-32, pls. 1-2, figs. 1-18; Taylor 1950: 143, pl. 38, fig. 1

ARNO ATOLL: H. 9524, H. 9544, Sta. 24.

*Heterosiphonia wurdemannii* var. *laxa* Børgesen 1915-20: 326, fig. 327 (Virgin Islands); Taylor 1950: 140 (as *H. wurdemannii*)

Fig. 60

KWAJALEIN ATOLL: D. 12568a, Sta. 1.

JALUIT ATOLL: D. 13108a, Sta. 18.

ARNO ATOLL: H. 9166, H. 9203a, H. 9444, H. 9538, Sta. 24; H. 9507, Sta. 28.

*Polysiphonia tongatensis* Harvey, in Kützinger 1864, Tab. Phyc. 14: 14, pl. 41 (Friendly Islands); Dawson 1954: 454, fig. 60d,e

JALUIT ATOLL: D. 13065a, D. 13075, Sta. 15. All reproductive phases present.

*Polysiphonia coacta* Tseng 1944: 71, pl. 2 (Hong Kong, China); Dawson 1954: 456, fig. 60g, h



FIG. 60. *Heterosiphonia wurdemannii* var. *laxa*: An upper part of a plant of D. 12568a, to show the branching and arrangement of cells,  $\times 25$ .



MAJURO ATOLL: D. 12729, Sta. 7.

ARNO ATOLL: H. 9534e, Sta. 24. The material in this mixture of turf algae is mostly 100–170  $\mu$  in diameter and in good agreement with this short-segmented Chinese species.

***Polysiphonia subtilissima* Montagne**

1840b: 199 (French Guiana); Dawson 1954: 454, fig. 60c

ARNO ATOLL: H. 9514, Sta. 28. This material of a very slender species with four pericentral cells, few scar cells, and almost no trichoblasts seems to agree with similar material collected by the writer in Viêt Nam and referred to this species in accord with Tseng 1944.

***Endosiphonia spinuligera* Zanardini 1878:**

35 (New Guinea); Falkenberg 1901: 571

Fig. 61



FIG. 61. *Endosiphonia spinuligera*: A small part of a plant of D. 13115,  $\times 3.5$ .

JALUIT ATOLL: D. 13115, Sta. 19. These specimens seem to be in complete agreement with this species described from New Guinea.

***Tolypocladia calodictyon* (Harv.) Silva**

1952: 308. *Polysiphonia calodictyon* Harvey, ex Kützinger 1864, Tab. Phyc. 14: 16, pl. 46, figs. a–c (Friendly Islands). Taylor 1950: 148, pl. 57, fig. 2 (as *Rochera calodictyon*)

Fig. 62

KWAJALEIN ATOLL: D. 12559, Sta. 1. Young, dwarfish material.

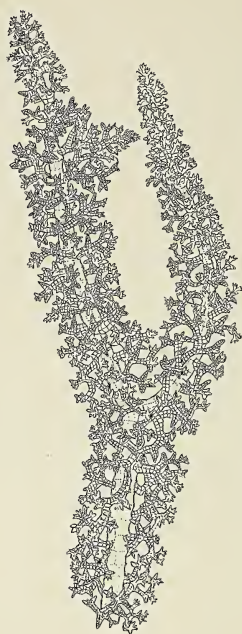


FIG. 62. *Tolypocladia calodictyon*: A small upper part of a plant of H. 9243,  $\times 6.5$ .

MAJURO ATOLL: D. 12784, Sta. 11.

JALUIT ATOLL: D. 13116, Sta. 19.

ARNO ATOLL: H. 9243, H. 9583, Sta. 25.

Occurring in huge quantities over a large area in the sandy inner section of the lagoon reef.

***Herposiphonia secunda* (Ag.) Ambronn**

1880: 197, pl. 4, figs. 8, 12; Howe 1920:

573, Børgesen 1930: 111, fig. 45. *Hutchin-*

*sia secunda* C. Agardh 1824: 149 (Mediterranean Sea)

Fig. 63

ARNO ATOLL: H. 9373c, Sta. 27; H. 9220, H. 9246b, H. 9258, H. 9290, Sta. 24. The plants of these collections agree with the species as interpreted by Howe (1920) who uses as a key character the fact that some of the nodes are regularly and wholly destitute of branches. The same is true of Børgesen's account. Taylor (1950: 148) reports a plant under this name from Rongelap Atoll, but his description does not agree with my specimens which have 7 to 8 pericentral cells in the main

axes, and do not have "erect branchlets at the three nodes between each two branch rudiments." His plants meet the usually accepted requirements for *H. tenella*.

***Herposiphonia tenella* (Ag.) Ambronn**  
1880: 197, pl. 4, figs. 9, 11, 13–16; Dawson  
1954: 452, fig. 59a. *Hutchinsia tenella* C.  
Agardh 1828: 105 (Mediterranean Sea)

KWAJALEIN ATOLL: D. 12615, Sta. 2.

JALUIT ATOLL: D. 13050a, Sta. 13; D.  
13103, Sta. 18; D. 13130, Sta. 19.

ARNO ATOLL: H. 9449a, H. 9534f, Sta. 24.

***Lophosiphonia villum* (J. Ag.) Setchell**  
and Gardner 1903: 329; Hollenberg 1942:  
535, figs. 11–13. *Polysiphonia villum* J.  
Agardh 1863: 941 (Tropical America)

Fig. 64

ARNO ATOLL: H. 9446, H. 9467b, Sta. 24.  
In these specimens the rhizoids are not cut  
off by a cross wall and are, thus, in agree-  
ment with the species as interpreted by Hol-  
lenberg and different from the superficially very sim-  
ilar *L. bermudensis*.

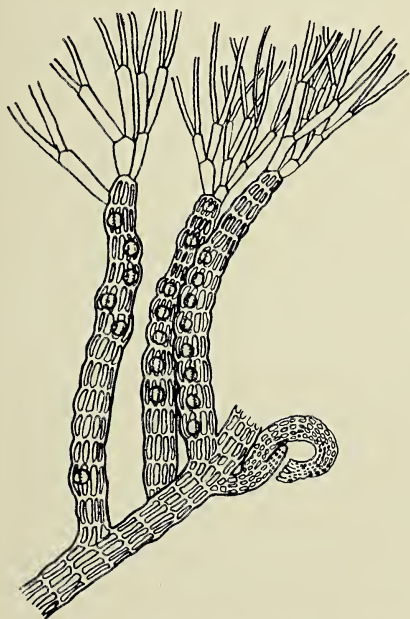


FIG. 63. *Herposiphonia secunda*: Part of a tetrasporic plant showing several segments lacking erect branchlets,  $\times 50$  (redrawn from Børgesen).

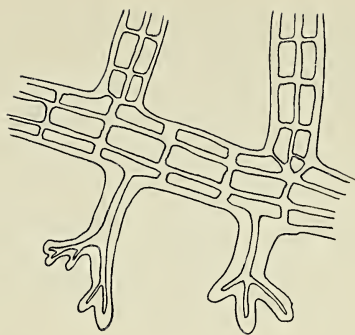


FIG. 64. *Lophosiphonia villum*: Part of a creeping basal filament showing the rhizoids which are not cut off by cross walls from the pericentral cells (H. 9446),  $\times 150$ .

***Lophosiphonia bermudensis* Collins and**  
Hervey 1917: 126, pl. 3, figs. 18–21 (Ber-  
muda). Dawson 1954: 451, fig. 58f, g (as  
*L. villum*)

Fig. 65

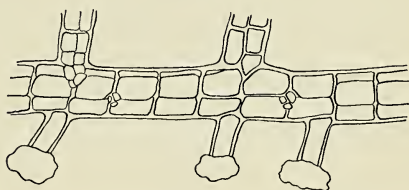


FIG. 65. *Lophosiphonia bermudensis*: A small part of a creeping basal filament showing the rhizoids distinctly cut off from the pericentral cells (H. 9598a),  $\times 130$ .

KWAJALEIN ATOLL: D. 12580, Sta. 1.

JALUIT ATOLL: D. 13003, Sta. 12; D. 13041,  
Sta. 13; D. 13071a, D. 13073, Sta. 15; D.  
13107, Sta. 18.

ARNO ATOLL: H. 9478, Sta. 28; H. 9598a,  
H. 9685c, Sta. 25.

The specimens cited above, of which some  
are in abundance and well-developed, as D.  
13071a, have rhizoids conspicuously cut off  
by a cross wall unlike those of *L. villum*. If  
this character proves to be a distinctive and  
specific one as it now appears to be, it is  
probable that many of the tropical specimens  
referred to *L. villum* may actually belong to  
*L. bermudensis*. Although Collins and Hervey



made no mention of the scar cells which occur in  $\frac{1}{4}$  spiral divergence and which in older axes are divided into 2–3 cells as shown in the figure above, these have been observed in typotype specimens of this species. These may in part develop into branches later.

*Laurencia mariannensis* Yamada 1931: 200, pl. 5, fig. b, text figs. F, G (Saipan, Marianas Islands); Taylor 1950: 144

Fig. 66

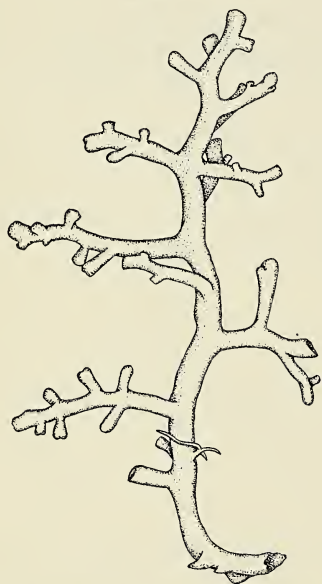


FIG. 66. *Laurencia mariannensis*: Habit of a small part of a plant of D. 12789,  $\times 4$ .

MAJURO ATOLL: D. 12789, Sta. 11.

ARNO ATOLL: H. 9581, Sta. 25.

The projecting surface cells near the ends of the branches are a conspicuous and distinctive feature of this species.

*Chondria repens* Børgeesen 1924: 300, fig. 40 (Easter Island); Dawson 1954: 460, fig. 62d, e

KWAJALEIN ATOLL: D. 12625, Sta. 2. This tetrasporic material which ranges from about 250 to 320  $\mu$  in diameter is somewhat more lax in habit than the Easter Island type as described and illustrated by Børgeesen, but is otherwise very much the same. D. 12662a, Sta. 5.

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# Descriptions and Redescriptions of the Hawaiian Octocorals Collected by the U. S. Fish Commission Steamer "Albatross"

## (2. Gorgonacea: Scleraxonia)<sup>1</sup>

FREDERICK M. BAYER<sup>2</sup>

THIS PAPER CONTINUES a general revision of the Octocorallia of Hawaiian waters, collected chiefly by the U. S. Fish Commission steamer "Albatross" during 1902. Part 1, which covered the Alcyonacea, Stolonifera and Telestacea, appeared in *Pacific Science*, volume 6, number 2 (1952). The present part commences the treatment of the Gorgonacea and considers the members of the suborder Scleraxonia, including the problematical genus *Keroeides*.

### Order GORGONACEA

The limits of this order are not very clearly defined. Those forms with a distinct axis, horny or calcareous, give comparatively little trouble. Their colonies are distinctive, their gastrovascular cavities are uniformly short, and they fall conveniently into the order as it is usually defined:

Octocorals building sessile, usually tree-like colonies. Zooids uniformly with short gastrovascular cavities connected with one another by gastrodermal solenia. Colonial coenenchyme divided into an outer and an inner layer. In the outer layer ("cortex" or "rind") the sclerites are free; in the inner

layer ("medulla" or "axis") the sclerites, if present, are surrounded by horny substance or are cemented together by calcareous matter to form a solid axis; or the axis may be purely horny, with or without non-spicular calcareous matter in the horny substance.

Unfortunately, there are all too many species that lack the characteristic features so commonly ascribed to the Gorgonacea. Several species long ranked in this order have recently (Verseveldt, 1940) been transferred on histological grounds to the Alcyonacea, making it difficult to distinguish clearly the former order from the latter. For all practical purposes, however, it would seem advisable to adhere more or less closely to the long-standing diagnosis of the Gorgonacea, and if a specimen shows a recognizable distinction between cortex and medulla, together with predominantly short gastrovascular cavities, to assign it to this order.

The peculiar genus *Keroeides*, although it has abundant spicular deposits in the outer layer of the axis, has a definite, chambered central chord and thus is clearly a holaxonian. However, it is here considered along with the Scleraxonia because of its general resemblance to them.

The order Gorgonacea is subdivided as follows:

1. The central axis is either purely horny, or horny with non-spicular (except in *Keroeides*) calcareous deposits often in coaxial

<sup>1</sup> Published with the permission of the Secretary of the Smithsonian Institution. Manuscript received June 23, 1955.

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- layers, or of long calcareous internodes alternating with short nodes of entirely horny material; often a chambered central chord in the axis: Suborder **HOLAXONIA**.
2. The central axis is not wholly or largely horny, but is instead a medullar zone filled with true spicules, often distinctly different from those of the rind, more or less tightly bound together by horny or calcareous matter; if jointed, the horny nodes are filled with spicules and the internodes are composed of inseparably fused spicular sclerodermites. Medulla never with a soft, cross-chambered central chord: Suborder **SCLERAXONIA**.

Suborder **SCLERAXONIA**

The subdivision of the Gorgonacea into its two suborders is likewise not entirely satisfactory. From a practical standpoint, the line separating the Scleraxonia from the Holaxonia should be drawn between those forms with spicules in the axis cylinder and those with the calcium carbonate of the axis in strictly non-spicular form, but the natural line falls elsewhere. Thus, the genus *Keroeides*, already mentioned, should be a scleraxonian on a basis of its spicular axis but is in reality a holaxonian.

The following key may assist in the recognition of the families, each represented by a single genus, discussed in the present paper.

1. The axis consists of spongy, spicule-filled, horny nodes alternating with longer calcareous internodes made up of spicules cemented together. . . . . Family **Melithaeidae**
1. The axis is not made up of alternating nodes and internodes . . . . . 2
2. The axis is a medullar region composed of completely fused calcareous sclerodermites derived from spicules . . . . .
- ..... Family **Coralliidae**
2. The axis is a medullar region composed of separable spicules bound together by horny material and sometimes by their

- own projections . . . . . 3
3. The axis has a cross-chambered central chord; axial spicules smooth, terete, more or less flattened, rather sinuous, occasionally anastomosing. . . . . Family **Keroeidae**
3. The axis may have numerous gastrodermal canals, especially in the proximal parts, but never a chambered central chord; axial spicules furnished with branching processes . . . . . 4
4. Polyps large, exsert, with a strong, well-defined anthocodial crown and points; monomorphic; cortex set off from medulla by a ring of boundary canals . . . . .
- ..... Family **Anthothelidae**
4. Polyps retractile into a thick cortex, not exsert; no strong anthocodial crown and points; dimorphic; cortex not set off from medulla by a ring of boundary canals . . . . .
- ..... Family **Paragorgiidae**

Family **PARAGORGIIDAE**

**DIAGNOSIS:** Dimorphic Scleraxonia with medullar region penetrated to the branch tips by gastrodermal canals and not separated from the cortex by a ring of boundary canals.

Genus **PARAGORGIA**  
Milne Edwards and Haime

*Paragorgia* Milne Edwards and Haime, 1857, Hist. nat. coral. 1: 190. Kükenthal, 1924, Das Tierreich 47: 28.

**DIAGNOSIS:** Colonies erect, often branched in one plane. Branches approximately round in cross section, usually knobby. Polyps dimorphic: autozooids large, completely retractile within low or hemispherical verrucae; siphonozooids small, in minute verrucae. Cortex with two layers, not separated from the medulla by boundary canals. Medulla perforated to branch tips by central, gastrodermal canals and smaller solenia. Spicules of the cortex chiefly capstans in the outer zone, spindles in the inner. Spicules of medulla mostly spindles or rods, coarsely spined and branched.

TYPE SPECIES: *Alcyonium arboreum* Linnaeus, by monotypy.

*Paragorgia dendroides* sp. nov.

Figs. 1; 2*d*

*Paragorgia nodosa* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 569. *Nec* Koren and Danielssen, 1883, Nye Alcyonider: VII, 18, pl. 9.

DIAGNOSIS: Slender *Paragorgia* with autozooids on all sides, often clustered, in dome-like verrucae; siphonozooids on cortex surface and autozooid verrucae as minute protuberances. Cortex divided into inner and outer layers by a network of small solenia; medulla with wide, central canals and large solenia. Outer cortical sclerites chiefly octoradiate capstans with blunt sculpturing; inner cortical sclerites as warty spindles. Medulla with longer, more rudely sculptured spindles. Tentacular rhachis with longitudinal tract of pointed rods mostly arranged lengthwise.

DESCRIPTION: The specimen consists of five fragments, the largest of which is 55 mm. in height; in its thickest part, the largest branch measures 6.5 mm. in diameter. Ramification is irregular and apparently not strictly in one plane. The autozooids occur singly or in clusters and form conspicuous, dome-like verrucae 2–3 mm. in height. Several autozooids usually are clustered at the twig tips making them clavate. The siphonozooids form much smaller verrucae, about 0.5 mm. in diameter, openly scattered on the surface of the cortex and on the autozooid verrucae. The canal system is complex and agrees in general with the description of that of *Paragorgia arborea* given by Verseveldt (1940: 20). There is a fairly distinct division of the coenenchyme into a cortical rind and a medullary axis.

The salmon pink cortex (including the walls of the autozooid verrucae) is divided into an inner and an outer layer by a network of cortical solenia that communicate between the zooids; smaller solenia penetrate both

inner and outer zones of the cortex. In the peripheral layer the typical sclerites are small capstans, chiefly octoradiates, 0.06–0.1 mm. in length (Fig. 1*b*). The cortical zone inside the solenial network is a thin, in places discontinuous, layer best developed in the verrucae, which contains warty spindles 0.2–0.23 mm. in length (Fig. 1*c*). The spicules of the cortex are pale pink.

The medulla, which is generally much paler in color than the cortex, is perforated by large solenia and, at the center, by three or four wide, longitudinal, gastrodermal canals, all intercommunicating through a system of smaller solenia. The pale peripheral part of the medulla contains large, colorless, coarsely warted rods up to about 0.4 mm. in length (Fig. 1*f*), and a very sparse scattering of pink spindles like those of the inner cortex. Immediately surrounding the large central canals is a pink area filled with colored sclerites shaped like those of the surrounding tissues but somewhat shorter and more rudely sculptured (Fig. 1*e*).

The autozooids have eight interseptal tracts of spicules extending up the tentacle bases and along the rhachis of the tentacles. Below the tentacles the sclerites are arranged obscurely *en chevron* between the septal insertions, becoming mostly longitudinal on the tentacle backs (Fig. 2*d*). Spicules do not extend into the pinnules, but the endodermal layer of the tentacles, including the pinnules, is charged with minute birefringent granules. The characteristic octoradiate capstan is a common form in the anthocodidae, but the principal spicule type in the tentacles seems to be the bluntly pointed rod with conical warts (Fig. 1*a*). There are also minute rods with spiny ends, a few crosses, and double forms.

HOLOTYPE: U.S.N.M. No. 25357. Ukula Point, Kauai, bearing S. 82°30'E., 13.1 miles distant, in 423–438 fathoms; fine coral sand, foraminiferans, rock; bottom temperature 41.0° F. June 24, 1902. "Albatross" station 4030.



REMARKS: The Hawaiian material was originally listed by Nutting under the name *Paragorgia nodosa* Koren and Danielssen. That species is generally considered to be identical with *Paragorgia arborea* (Linnaeus), and the original figures of the spicules of *P. nodosa* tend to support such a conclusion. Although it is impossible to decide if the Hawaiian "*Paragorgia nodosa*" is the same as the "*Paragorgia nodosa*" recorded by Nutting (1912) and Kinoshita (1913) from Japan (their specimens are lost), it is certainly not *P. arborea* (see Fig. 2). The Hawaiian material may prove to be the same as one of Kinoshita's provisionally described species, *Paragorgia tenuis* and *P. granulosa*, but, without reference to type material, this is another question that must go unanswered. During a recent visit to Tokyo I was unable to locate Kinoshita's type specimens of *Paragorgia* among the collections of the Zoological Institute, Tokyo University, where many of his types are preserved. The only course is to establish the Hawaiian specimen as a new species until additional material is available to clear up the problem.

#### Family CORALLIIDAE

This distinctive family of scleraxonians is unique in possessing an unjointed axial cylinder, or medulla, of solid calcium carbonate. According to recent authors, it contains but two valid genera. These may be separated thus:

Among the spicules there are numerous regular capstans: Genus *Corallium* Cuvier

Among the spicules there are rods, plates, and irregular forms, but no capstans: Genus *Pleurocoralloides* Moroff

For the coralliums proper, J. E. Gray (1867) proposed the use of three genera based upon the form of verrucae and the manner of branching: *Corallium*, for *C. rubrum*; *Pleurocorallium*, for *C. secundum*; and *Hemicorallium*, for *C. johnsoni*. In regard to spicules, *C. secundum* and *C. johnsoni* differ widely from *C. rubrum*, the former two have double clubs

whereas the latter has only capstans. On this account, Ridley (1882) later recognized *Pleurocorallium* (including *Hemicorallium*) as distinct from *Corallium*. Most modern workers, however, recognize only *Corallium*, with *Pleurocorallium* and *Hemicorallium* as junior subjective synonyms.

The genus *Pleurocoralloides* Moroff, originally described from Japan, is not thus far known from the Hawaiian Islands.

#### Genus CORALLIUM Cuvier

*Madrepora* (pars) Linnaeus, 1758, Syst. Nat. Ed. 10, 1: 797.

*Corallium* [ächte rothe Steincoralle] Müller in Knorr, 1766, Delic. Nat. 1: 7, pl. A I, figs. 1, 2; p. 23, pl. A VII, fig. 1; p. 24, pl. A VIII, figs. 2-4; p. 127 (pars); nec pp. 9, 10, 11, 12, 13, 25, 128. [The generic names published in this work, though cited both by Neave, *Nomenclator Zoologicus*, and by Schultze, *Nomenclator Animalium*, are unavailable as the work is non-binominal.]

*Isis* (pars) Linnaeus, 1767, Syst. Nat. Ed. 12, 1 (2): 1288.

Nec *Isis* Linnaeus, 1758, Syst. Nat. Ed. 10, 1: 799.

Nec *Corallium* Burman, 1769, Index alter Herb. Amb. p. [3]. [= *Isis* Linnaeus, 1758.]

*Corallium* Cuvier, 1798, Tabl. élém.: 673. Lamarck, 1801, Syst. anim. s. vert.: 378. Gray, 1867, Zool. Soc. Lond., Proc.: 126. Ridley, 1882, Zool. Soc. Lond., Proc.: 221. Kishinouye, 1904, Imp. Fish. Bur. Tokyo, Jour. 14: 20. Hickson, 1907, Siboga Exped. Monog. 13c<sup>1</sup>:2.

*Hemicorallium* Gray, 1867, Zool. Soc. Lond., Proc.: 126.

*Pleurocorallium* Gray, 1867, Zool. Soc. Lond., Proc.: 126. Ridley, 1882, Zool. Soc. Lond., Proc.: 221. Johnson, 1899, Zool. Soc. Lond., Proc.: 57.

As can be seen from the synonymy above, the name *Corallium* has a rather motley history. It is an old name of dubious origin, going back to the ancient Greeks, classically applied to the red coral of commerce, the

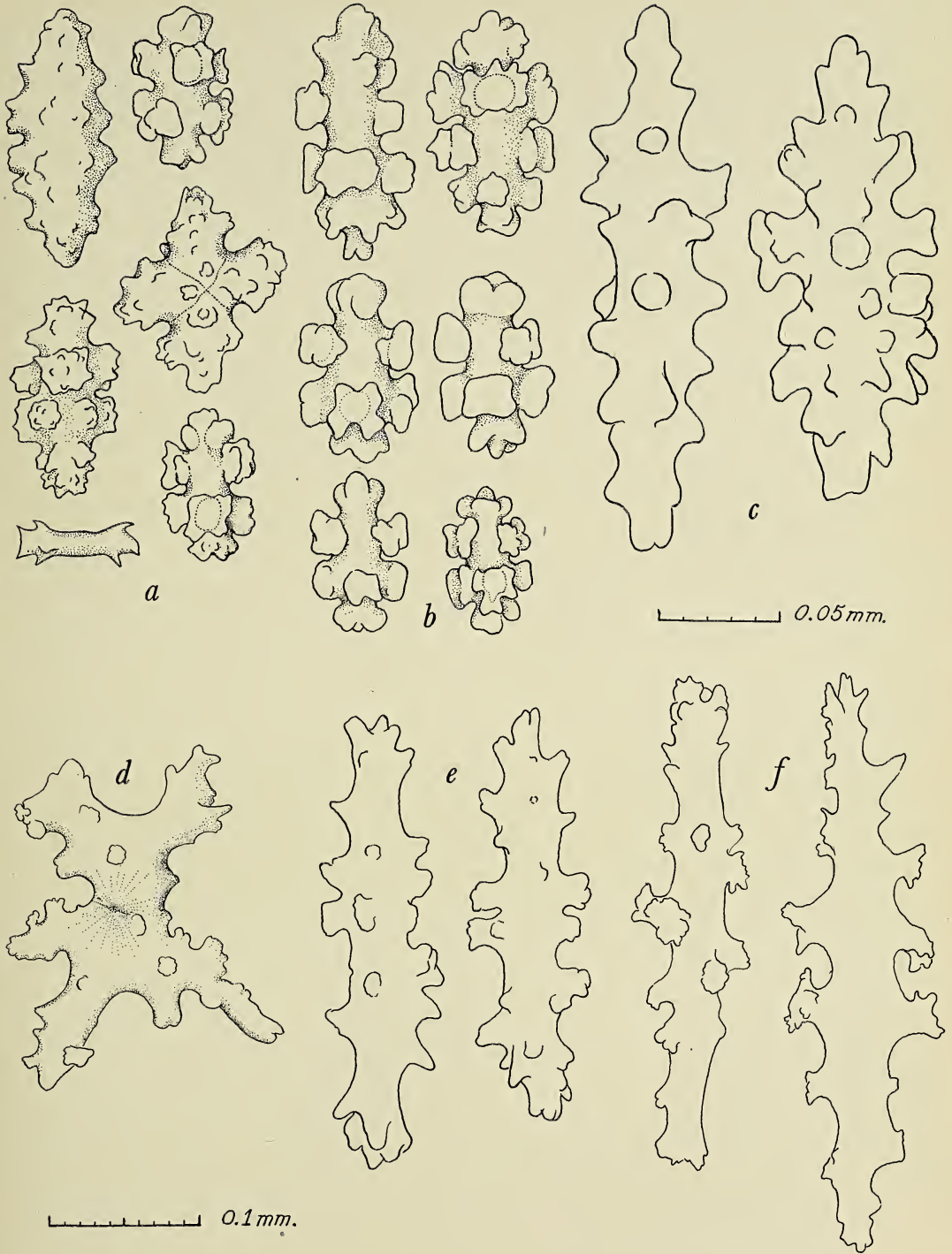


FIG. 1. *Paragorgia dendroides* sp. nov. Spicules of: *a*, Anthocodia; *b*, outer cortex; *c*, inner cortex; *d*, medulla; *e*, medulla surrounding main stem-canals; *f*, peripheral zone of medulla. Scale at *c* applies to *a-c*; scale at *d* applies to *d-f*.



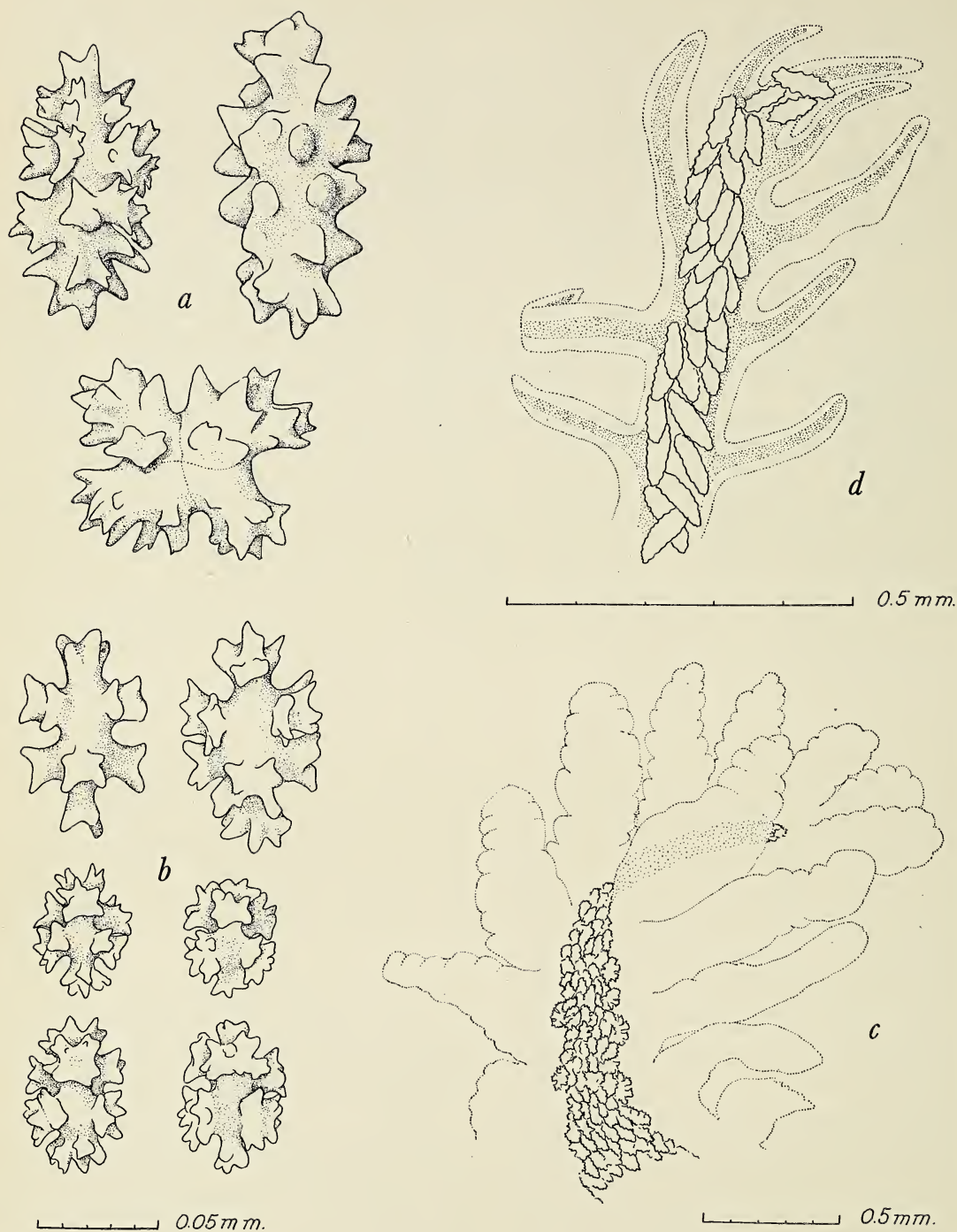


FIG. 2. *a-c*, *Paragorgia arborea* (Linnaeus). *a*, Spicules of anthocodia; *b*, spicules of outer cortex; *c*, tentacle (the stippled area indicates the course of the spicular tract where it is concealed by a pinnule). *d*, *Paragorgia dendroides* sp. nov., tentacle (the stippled area indicates distribution of miliary granules). Scale at *b* applies to *a* and *b*; scales at *c* and *d* to those figures only.

"true red stony coral." Unfortunately, one of the applications of the name *Corallium* to a different coral (Burman, 1769) antedates Cuvier's publication of it in the usual sense by almost 30 years and thus threatens the time-honored usage of the name. If the generic names in Burman's Index to the *Herbarium Amboinense* are nomenclaturally available, *Corallium* Cuvier must be conserved by the International Commission on Zoological Nomenclature or disappear as a junior synonym of *Isis* Linnaeus.

**DIAGNOSIS:** Dimorphic Scleraxonia with solid axis composed of calcareous sclerodermites derived from spicules. Cortical spicules are modified capstans with six, seven, or eight radii, double clubs derived from capstans, spindles, rods, crosses, and irregular forms.

**TYPE SPECIES:** *Madrepora rubra* Linnaeus, 1758 (by subsequent monotypy, the first species being assigned by Lamarck, 1801).

**REMARKS:** The various species of *Corallium* are identified by the arrangement, shape, and

distribution of autozoid verrucae; the manner of branching; and the types of spicules present in the verrucae and in the rind.

The character of branching is convenient for identification, since it seems to remain constant within species, but it is not a primary character in determining relationships. The differences in spiculation are useful both in determining and in relating the various species. The basic type of spicule appears to be the octoradiate capstan. It is found in most species and is the prototype of the other forms, which have been produced by the suppression, modification, and exaggeration of certain radii. Color is not always a reliable feature since it may vary within the species, but is a useful secondary character.

The types of spicules found in *Corallium* are:

1. Long rods or spindles, with more or less prominent, simple warts. This type occurs principally in the autozoid verrucae and the tentacles.

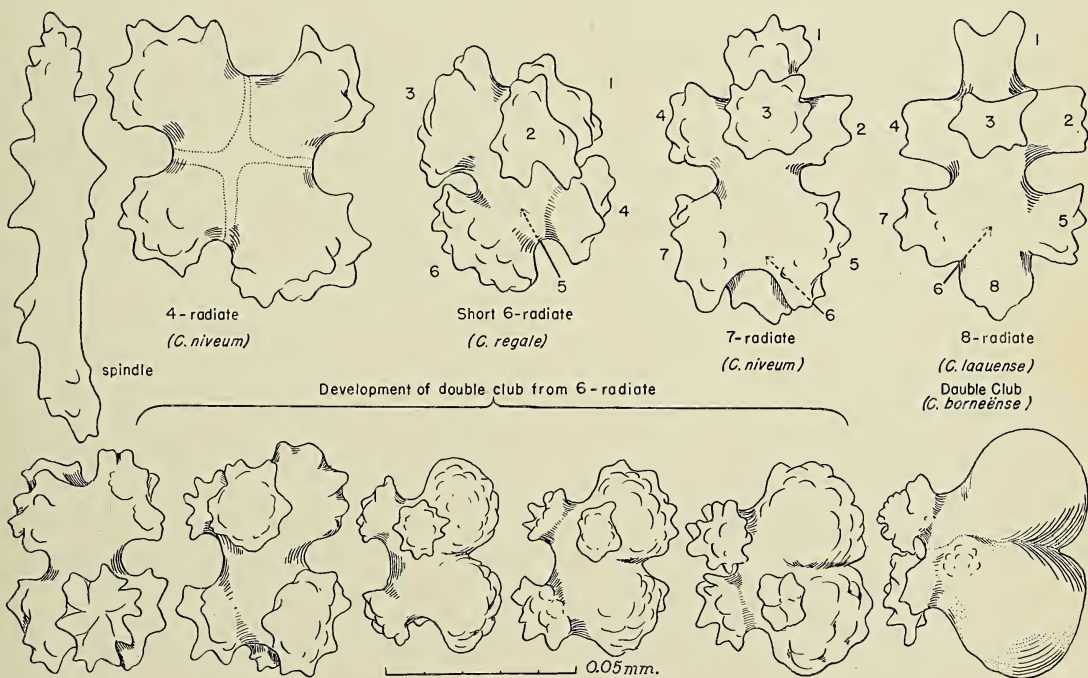


FIG. 3. Spicule types in the genus *Corallium*.



## 2. Multiradiate forms:

- a. Crosses or 4-radiates (Kreuze).
- b. Capstans (Gürtelstäbe), with 6, 7, or 8 radii (Sechser, Siebener, Achter). The length of the "waist" or smooth girdle may vary considerably; in a few species, the shaft of the 6-radiates may be so abbreviated that the spicules are nearly spherical (Fig. 9g). This is the irregular form that Kükenthal describes in *C. tricolor* ("zahlreiche unregelmässige, fast kugelige, mit dicken, ausstrahlenden Fortsätzen bedeckte Skleriten") and *C. maderense* ("unregelmässig strahlige Kugeln"), but it is not the same as the irregular type of *C. bōshūense* and *C. sulcatum*.
3. Double clubs, "double carafes" or "opera-glass spicules" (Doppelkeulen). These are derived from capstans, as shown in Figure 3.
4. Irregular forms, which are massive, lumpy sclerites of the sort found in *Corallium bōshūense* and *C. sulcatum* from Japan, and in *C. ducale* from Guadalupe Island, west Mexico. This type of spicule is not found in any of the six species now known from Hawaiian waters.

Although modern students place all species of capstan-bearing Coralliidae in the one genus *Corallium*, there actually are groups of closely related species within the genus. Disregarding the sad experiences of others, I attempted anew to bring these groups into some logical arrangement. This has proved to be even more hopeless than it was half a century ago when Kishinouye studied the problem. After long and serious consideration, I can do no more than to point out certain of the relationships in the hope that some eye more penetrating than my own may detect among them a clue to the solution.

One very distinct group of species includes those that have in common double club spicules, hemispherical verrucae, and papillate rinds. Two species, *Corallium secundum* and *C. elatius*, constitute the group.

Another is the group of species that have pits in the axis beneath the autozooids. *Corallium stylasteroides* and *C. tortuosum* are very closely related, and have no double club spicules; *C. inutile* and *C. japonicum* are similar in many respects to the former pair, but have well-developed double clubs. The original precious coral, *C. rubrum*, may also belong with this group.

Perhaps the most circumscribed and homogeneous group of all is the one characterized by thick cortex, hemispherical verrucae in clusters, and double club spicules. It appears to be a very closely knit complex of species including *Corallium kōnojoī*, *C. borneense*, *C. niveum*, and *C. pusillum*.

The final group, easily as diverse as the preceding one is uniform, is a perplexing array of species characterized by one feature: long spindles in the autozooid verrucae, which are usually tall. The species vary in form from profusely branched to only sparsely ramified; they may or may not have double club spicules; and some have cortical papillae (aside from siphonozooids) while others have not. The group includes *Corallium sulcatum*, *C. laauense*, *C. regale*, *C. abyssale*, *C. bōshūense*, *C. variabile*, *C. halmabeirensis*, *C. johnsoni*, *C. tricolor*, *C. maderense*, *C. imperiale*, and *C. ducale*. *Corallium reginae* Hickson has verrucal spindles but, unlike the other species just listed, it has low, hemispherical verrucae. It is of interest to note that, of the three species having short, nearly globular 6-radiates, two (*maderense*, *tricolor*) are Atlantic while one (*regale*) is Hawaiian. *Corallium sulcatum*, *C. bōshūense* and *C. ducale*, all with massive, irregular sclerites, may form a sub-group.

Of the 20 species of *Corallium* known to inhabit the Indo-Pacific region, six are at present known from Hawaiian waters, and two from the eastern Pacific off Baja California (Guadalupe Is.). These may be separated as follows:

1. The autozooid verrucae and tentacles contain long spindles with conical processes  
..... 2

1. The autozoid verrucae and tentacles have no long spindles. . . . . 6
2. Double clubs present. . . . . 3
2. Double clubs not present. . . . . *laauense* sp. nov.
3. Autozooids biserial; branching dichotomous with alternate branches dominant, thus producing a zigzag stem. . . . . *abyssale* sp. nov.
3. Autozooids directed toward one face of the colony, not biserial; stem not zigzag. . . . . 4
4. Branching symmetrically dichotomous, in one plane; calyces short-cylindrical or blunt-conical; massive, irregular sclerites present. . . . . *ducale* Bayer
4. Branching chiefly pinnate; calyces tall, cylindrical. . . . . 5
5. Verrucae with eight grooves extending their full length. The 6-radiate spicules are of ordinary form and not almost spherical; 7-radiates are not uncommon; 8-radiates and double clubs abundant. . . . . *imperiale* Bayer
5. Verrucae grooved only in the apical part, otherwise practically smooth. The 6-radiate spicules are short, almost spherical, often with the radii much reduced; 7-radiates quite rare; 8-radiates and double clubs abundant. . . . . *regale* sp. nov.
6. Double clubs present. Axis not pitted beneath the autozooids. . . . . 7
6. Double clubs not present; crosses numerous. Axis with distinct pits, often with raised and beaded rims, beneath the autozooids. . . . . *tortuosum* sp. nov.
7. Rind practically smooth, white, moderately thick. Verrucae large, often clustered in groups. . . . . *niveum* sp. nov.
7. Rind strongly papillate, salmon-pink, rather thin. Verrucae small, not clustered in groups except on twig tips. . . . . *secundum* Dana

In view of the possibility that species of *Corallium* described from other parts of the Indo-Pacific may occur also in Hawaii, the following key to all 20 species known from that area is offered as a double check upon determinations made by use of the regional key.

KEY TO THE SPECIES OF *Corallium* KNOWN  
FROM THE INDO-PACIFIC REGION

1. Autozooids occur all around the stems and branches. . . . . 17
1. Autozooids are more or less strictly biserially arranged or predominantly face one side of the colony. . . . . 2
2. Spindles with simple warts are present in the distal part of the autozoid verrucae and in tentacle backs. . . . . 3
2. No spindles in autozoid verrucae. . . . . 12
3. Double clubs present. . . . . 4
3. Double clubs not present. . . . . 11
4. Massive, irregular sclerites present. . . . . 5
4. Massive, irregular sclerites not present. . . . . 7
5. Ramification in one plane, openly branched in a predominantly dichotomous plan; no branchlets much smaller than the main branches arising from the front of the colony. . . . . *ducale* Bayer (Guadalupe Is., Mexico)
5. Primary branching in one plane, but numerous slender branchlets much smaller than the main branches arising from the front of the colony. . . . . 6
6. Axis white, rind yellow, not furrowed. Autozoid verrucae tall, cylindrical, not conspicuously grooved. . . . . *bōshūense* Kishinouye (Japan)
6. Axis pink, rind light red, longitudinally furrowed. Autozoid verrucae cylindrical, with eight conspicuous grooves. . . . . *sulcatum* Kishinouye (Japan)
7. Rind with double clubs and 8-radiate spicules only; no 6- and 7-radiate forms. . . . . 8



7. Rind with 6-radiates as well as 8-radiates and double clubs. . . . . 9
8. Autozoid verrucae hemispherical, 1.5 mm. in height. Cortex red, axis dark pink with pale concentric rings. . . . .  
     . . . . . *reginae* Hickson (East Indies)
8. Autozoid verrucae cylindrical. . . . . 10
9. Outer walls of autozoid verrucae distinctly grooved their full length along the lines of septal insertion. Rind with 6-, 7-, and 8-radiates, double clubs and crosses. . . . . *imperiale* Bayer  
     (Guadalupe Is., Mexico)
9. Outer walls of verrucae with grooves in the distal part only, and there not always distinctly. Rind with short, spheroidal 6-radiates, 8-radiates and double clubs; 7-radiates uncommon. . . . .  
     . . . . . *regale* sp. nov. (Hawaii)
10. Autozoid verrucae widely separated (8-10 mm. apart), biserial, 2 mm. in height; branching sparse, the main stem zigzag. . . . . *abyssale* sp. nov. (Hawaii)
10. Autozoid verrucae closely and irregularly placed, facing one side of the colony, 2.7 mm. in height; branching profuse. . . . .  
     . . . . . *variabile* (Thomson and Henderson)  
     (Ceylon)
11. Spindles of verrucae reaching 0.15 mm. in length; 8-radiates frequently exceeding 0.10 mm. Rind with prominent papillae; color white. Axis white. . . . .  
     . . . . . *laauense* sp. nov. (Hawaii)
11. Spindles of verrucae about 0.09 mm. in length; 8-radiates up to 0.07 mm. Rind not papillate; color orange red. Axis pink. . . . .  
     . . . . . *halmaheirens* Hickson (East Indies)
12. Double clubs present. . . . . 13
12. Double clubs not present. Spicules are 6-, 7-, and 8-radiates and crosses. . . . .  
     . . . . . *japonicum* Kishinouye (Japan)
13. Octoradiates present. . . . . 14
13. Octoradiates not present. . . . . 16
14. Autozoid verrucae in clusters. Rind not papillate. Twigs thick and stubby. . . . 15
14. Autozoid verrucae evenly distributed, not in clusters (except at tips of twigs). Rind densely papillate. Twigs slender, abundant on front face of colony. . . . .  
     . . . . . *secundum* Dana (Hawaii)
15. With both 6- and 7-radiates. White. . . . .  
     . . . . . *niveum* sp. nov. (Hawaii)
15. Without 6- and 7-radiates. Orange. . . . .  
     . . . . . *pusillum* Kishinouye (Japan)
16. Autozoid verrucae clustered in groups. Rind smooth. End twigs thick. . . . .  
     . . . . . *kōnoji* Kishinouye (Japan)
16. Autozoid verrucae evenly distributed, not in groups. Rind papillate. End twigs slender. . . . . *elatus* (Japan)
17. Double clubs present. . . . . 18
17. Double clubs not present. . . . . 19
18. Rind very thin. Axis with pits beneath the autozooids. Other spicules are 6-radiates. . . . . *inutile* Kishinouye (Japan)
18. Rind thick. Axis without pits beneath the autozooids. Other spicules are 6-, 7-, and 8-radiates and crosses. . . . .  
     . . . . . *borneense* Bayer (Borneo)
19. Spicules only 8-radiates. Axis white. . . . .  
     . . . . . *stylasteroides* Ridley (Mauritius)
19. Many crosses present in addition to 8-radiates. Axis pink. . . . .  
     . . . . . *tortuosum* sp. nov. (Hawaii)

*Corallium abyssale* sp. nov.

Fig. 4; 5a; 7a-d

DIAGNOSIS: Branching asymmetrically dichotomous, especially proximad, in one plane. Autozooids biserial, verrucae with spindles. Siphonozooids in groups around autozooids. Rind papillate. Spicules: crosses, 8-radiates, double clubs; spindles in verrucae.

DESCRIPTION: The colony branches in one plane in an asymmetrically dichotomous manner, alternate branches dominating to produce

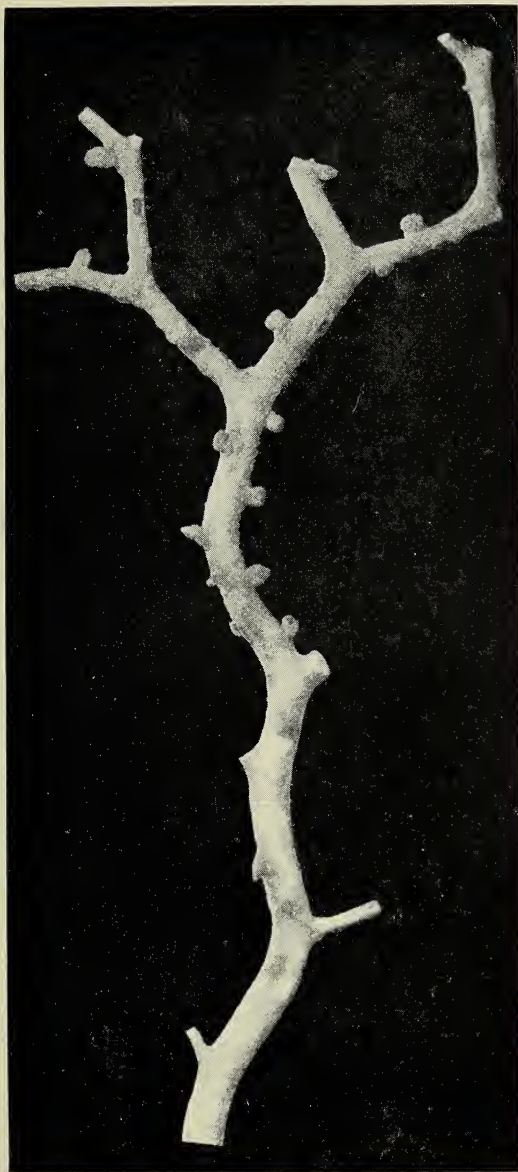


FIG. 4. *Corallium abyssale* sp. nov. The type specimen.

a zigzag, sympodial main stem; in the upper part of the colony the dichotomy becomes symmetrical and quite regular. The axis is solid, round, and smooth, 4 mm. in diameter at the lowest point, tapering to 2.5 mm. at the top (no twig tip is preserved intact). The autozooids are very widely separated and few in number, essentially biserial in arrangement although an occasional individual is out of

line; the verrucae are 2 mm. in height, cylindrical, with eight longitudinal grooves in the distal half, corresponding to the septal insertions. The siphonozooids form low, wart-like protuberances in groups around the autozooids. The surface of the rind bears in addition scattered, prominent papillae that are smaller than siphonozooids and probably represent nematocyst batteries. The rind is extremely thin and is rubbed off in places.

The spicules of the autozooid verrucae include long, blunt spindles 0.12–0.13 mm. long in addition to the forms found in the rind proper. The rind spicules are 8-radiates, often coarse and clumsy-looking; stubby crosses; and double clubs with wide, depressed, weakly sculptured heads and short handles with radiating processes. In the oral disk and pharyngeal region there are spiny rodlets that appear to be derived from the 8-radiate type.

The rind (in alcohol) is pale brown, probably discolored; the axis is pale pink with a somewhat darker center; the spicules are colorless.

HOLOTYPE: U.S.N.M. No. 49326. Off Kauai: Hanamaulu warehouse bearing South 49°30' West, 8.4 miles distant; depth, 1000–1314 fathoms, gray sand, mud, and foraminiferans; bottom temperature 36.6° F. "Albatross" station 4185, August 13, 1902.

REMARKS: *Corallium abyssale* does not closely resemble any other known species of the genus, although it is like *C. sulcatum* Kishinouye and several other species in having tall, sulcate verrucae with spindles in the spiculation.

According to the original field label, this specimen was "pink" when fresh.

#### *Corallium regale* sp. nov.

Figs. 5c; 7e–g

DIAGNOSIS: Autozooids on front and two sides of branches; verrucae tall, cylindrical, grooved only at their distal tips, containing



long, irregular spindles. Siphonozooids visible as simple pores on bases of autozooids and rind. Rind smooth. Spicules: short, globose 6-radiates, 7-, and 8-radiates (the 7's quite rare), crosses, double clubs; spindles in autozoid verrucae only. Color pink.

**DESCRIPTION:** The type consists of a branch with a few short twigs, insufficient to show the pattern of branching. The axis is round, smooth, and solid. The autozooids are arranged along two sides and one face, leaving the rear of the branch bare; they form tall, cylindrical verrucae 1.5–2.0 mm. in height and 1.5 mm. in diameter, 8-lobed and grooved toward the distal ends. The siphonozooids appear as small pores, sometimes in small, wart-like protuberances, on the bases of the autozooids and on the rind. The surface of the rind is not papillate, although there are surface irregularities. The rind is moderately thick, and in places expanded from the sides of the branches as recurved flaps supported by thin, calcareous outgrowths of the axis, to form tunnels inhabited by polychaete commensals.

The autozoid verrucae contain long, irregular rods 0.09–0.12 mm. in length. In both verrucae and general cortex are found 6-, 7-, and 8-radiates, the first usually short, often with the radii much reduced; the 7's of usual form, quite uncommon; the 8's also of usual form, common; also a few crosses, and double clubs with rudely sculptured heads. Small, spinose rodlets are present in the oral disk and pharyngeal region.

The spicules are pale pink by reflected light. The colony as a whole, including the axis, is pale pink.

**HOLOTYPE:** U.S.N.M. No. 49520. French Frigate Shoal: 23°47'10" North, 166° 24' 55" West; 395–387 fathoms; coarse sand, shell, coral rock; bottom temperature 41.0° F. "Albatross" station 3973, May 29, 1902.

**REMARKS:** The scant material at hand gives little indication of the appearance of the en-

tire colony. The branching is probably in one plane, as indicated by the origin of the twigs from the sides of the branch, and furthermore probably is pinnate.

*Corallium regale* is most closely related to *Corallium sulcatum* Kishinouye and *C. imperiale* Bayer, but differs from both in having the peculiar, almost spherical 6-radiates found also in *C. maderense* and *C. tricolor* of the Atlantic.

Of all the Hawaiian precious corals, *C. regale* has the best color and might be of commercial value if it could be fished in quantity.

*Corallium laauense* sp. nov.

Fig. 5e, f; 7b–j

**DIAGNOSIS:** Verrucae cylindrical, longitudinally grooved, placed on two sides and front of branches, containing long spindles. Surface of rind costate, with scattered, conical papillae. Rind with cruciform and 8-radiate spicules.

**DESCRIPTION:** The material at hand consists of some terminal twigs that give off lateral branchlets in one plane. The autozooids are distributed on two sides and the front of the branches; they form cylindrical, longitudinally grooved verrucae about 1 mm. tall. The siphonozooids appear as small warts with an apical pore, near the autozoid bases. The rind is longitudinally costate and bears small, conical papillae. In some of the branch axils the rind extends as a thin, membranous expansion as it may also do along the two edges of the twigs, where it may be recurved, the margins of opposite sides joining to form closed tunnels. The axis is practically round, and in the largest parts preserved shows an indication of broad, longitudinal grooving.

The spiculation consists of blunt, spinose rods or spindles up to 0.145 mm. long in the autozoid verrucae; crosses and 8-radiates in verrucae and rind; and the usual small rods in the pharyngeal region and oral disk.

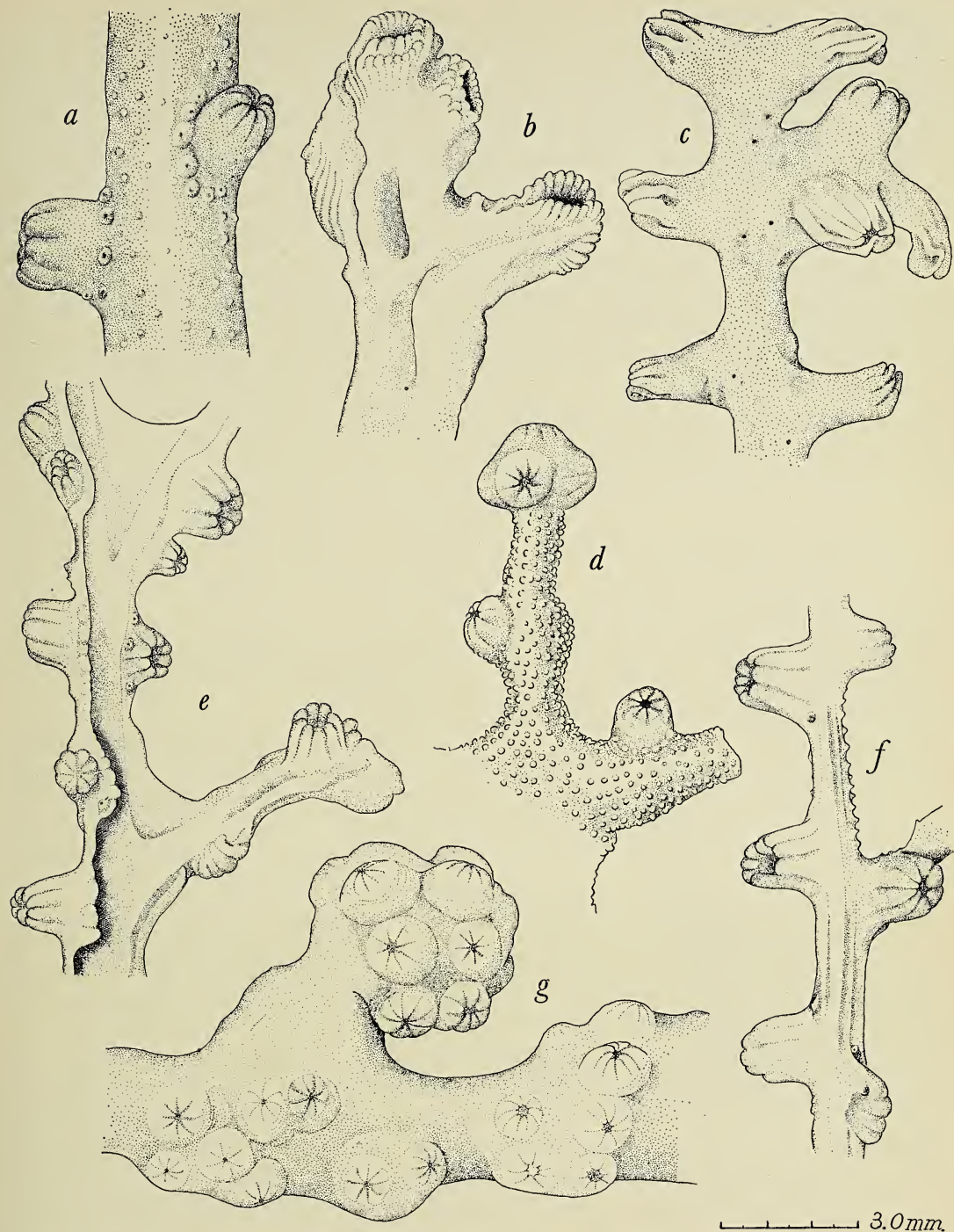


FIG. 5. *a*, *Corallium abyssale* sp. nov.; two autozooids on branch from upper part of colony; *b*, *C. tortuosum* sp. nov., tip of branch, cortex removed; *c*, *C. regale*, sp. nov., tip of branch; *d*, *C. secundum* Dana, one of the small twigs from front of colony; *e-f*, *C. laauense* sp. nov., two branchlets, *e* with the coenenchymal flaps induced by the presence of commensal polychaete; *g*, *C. niveum* sp. nov., one of the decurved, clavate twigs from front of colony; left is distad. Scale applies to all figures.



The rind is white or faintly pink; the axis is white. Spicules colorless.

HOLOTYPE: U.S.N.M. No. 49327. Molokai Island: Lae-o Ka Laau Light bearing North 46° West, 11 miles distant; depth 319–281 fathoms; broken shell and gravel; bottom temperature 43.8° F. "Albatross" station 3828, April 1, 1902.

REMARKS: In the form of its calyces and its seemingly finely divided branching, *Corallium laauense* resembles *C. sulcatum* Kishinouye, but the latter has double clubs and massive, irregular forms among its spicules.

The flaps and tunnels of rind are induced by the presence of a commensal polychaete annelid belonging to the family Polynoidae.

### *Corallium secundum* J. D. Dana

Fig. 5*d*; 6*d*, *e*; 8*a–d*

*Corallium secundum* Dana, 1846, U. S. Expl. Exped., Zooph.: 641, pl. 60, fig. 1. Kishinouye, 1904, Imper. Fish. Bur., Tokyo, Jour. 14: pl. 6. Kükenthal, 1924, Das Tierreich 47: 49.

*Pleurocorallium secundum* Ridley, 1882, Zool. Soc. Lond., Proc.: 224, pl. 9, figs. 6–11. ?Wright and Studer, 1889, Challenger Zool. 31 (1): 186.

DIAGNOSIS: Branching in one plane, with slender, prickle-like twigs on front surface of colony. Autozoid verrucae hemispherical, distributed on front surface of branches and on the twigs. Siphonozooids near bases of autozooids. Rind prominently papillate. Spicules: crosses, 6-, 7-, and 8-radiates, and double clubs. Verrucae without long spindles.

DESCRIPTION: Colonies with the major branching in one plane, flabellate; the small twigs are slender and prickle-like and occur only on the front face of the colony. The solid axis is somewhat flattened at right angles to the major plane of ramification, and is longitudinally striated. The autozoid verrucae, which are restricted to the side of the

colony that bears the short twigs, are evenly distributed and not clustered in groups except at the tips of the twigs where there may be two or three. The siphonozooids occupy small verrucae near the autozoid bases. The rind is closely papillate on all sides of the branches, but more densely so on the front. Sections have not been made to determine the nature of the papillae.

The principal spicule type is the double club; large, well-formed 8-radiates are present but not common; 6- and 7-radiates are comparatively rare. The tentacles have small 8-radiates, and in the pharyngeal region there are spiny rods and crosses of small size. The verrucae have no long spindles.

The rind is salmon pink, the verrucae not noticeably different in color. The axis is pale pink, often almost white, sometimes with a darker center. The spicules are pink by reflected light.

HOLOTYPE: U.S.N.M. No. 600. Sandwich Islands [Hawaiian Islands]. United States Exploring Expedition.

RECORDS: Pailolo Channel, between Molokai and Maui: Mokuhooniki Islet bearing North 31° West, 2.7 miles distant; depth 127–154 fathoms; broken coral, coarse gravel, rock; bottom temperature 60°–61° F. "Albatross" station 3863, April 10, 1902.

Mokuhooniki Islet bearing North 27° West, 3.3 miles distant; depth 136–148 fathoms; sand and pebbles; bottom temperature 64.8° F. "Albatross" station 3885, April 17, 1902.

REMARKS: *Corallium secundum* was long known only from the unique type, which is now decorticated. The locality "Sandwich Islands" also was held open to question. The description and figures of the spiculation given herein were made from specimens taken at two "Albatross" stations as mentioned above.

A polychaete annelid of the family Polynoidae infests this coral, causing it to produce covered tunnels along the twigs and branches.

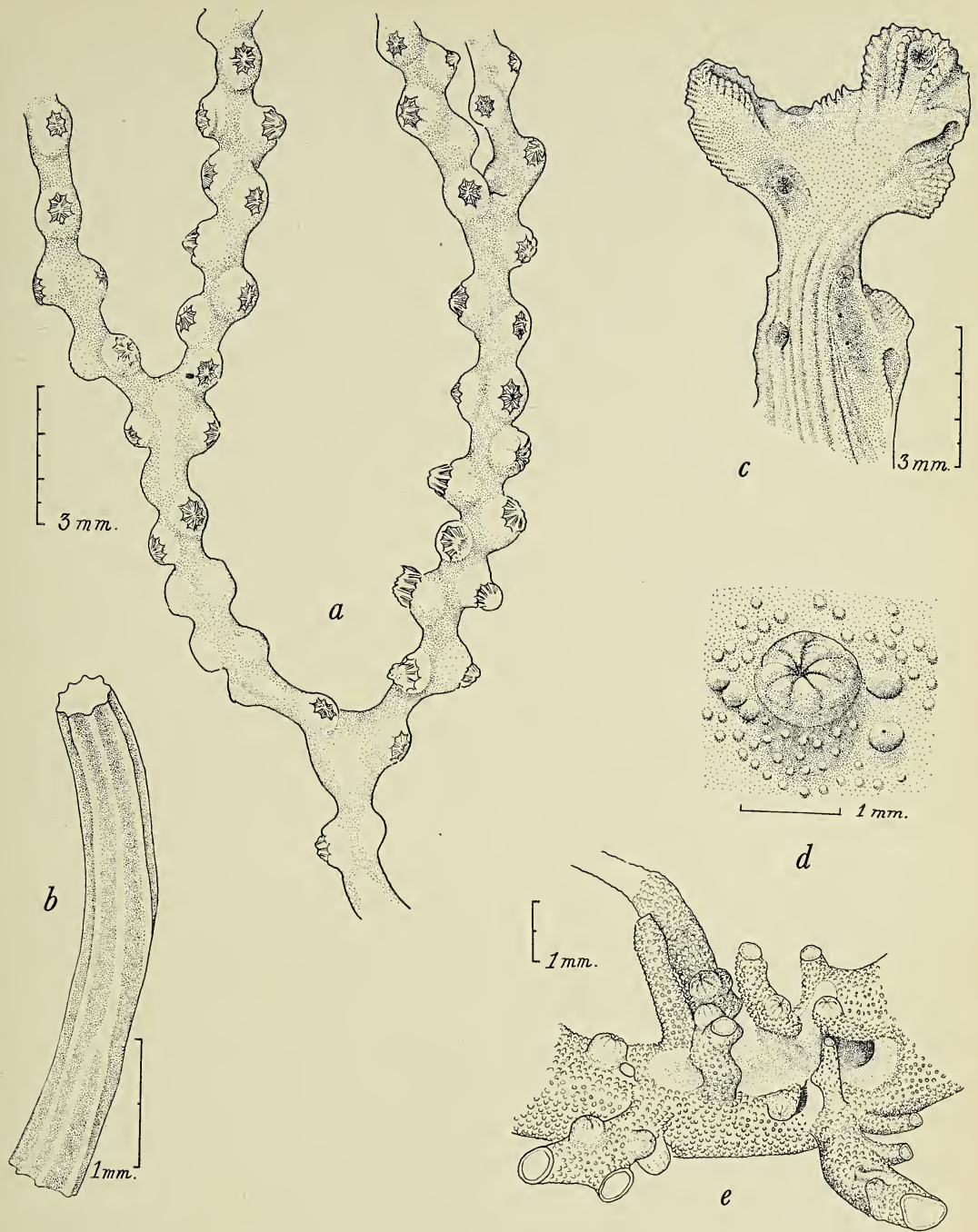


FIG. 6. *a, b*, *Acabaria bicolor* (Nutting): *a*, Part of the type specimen; *b*, part of axial internode, cortex removed; *c*, *Corallium tortuosum* sp. nov., branch tip with rind intact; *d-e*, *Corallium secundum* Dana, *d*, part of branch with worm tunnel; *e*, autozooid verruca with adjacent siphonozooids and cortical papillae.



*Corallium tortuosum* sp. nov.

Fig. 5b; 6c; 8e-g

DIAGNOSIS: Colonies irregularly branched in one plane. Autozooids on all sides, seated in calycular pits in the solid axis. Rind thin. Siphonozooids scattered. Spicules: crosses and 8-radiates only, in both rind and verrucae; small crosses and irregular rodlets in pharyngeal region.

DESCRIPTION: The colonies are irregularly branched, but show a definite tendency to remain in one plane. The trunk is round or oval in cross section, about 10 mm. in diameter and longitudinally grooved; the smaller branches are basically round in cross section but are more or less distorted by the autozoid calyces which indent the solid axis. The autozooids appear as raised areas on the trunk and branches; each is set in a depression surrounded by a raised rim. This rim is usually highest above and open toward the base of the colony, so that the calycular margin forms a projecting shelf over the zoid. The calyces on the twigs usually have the best developed rims, and since two are often opposed at the twig tips, a cross section of the axis there assumes a roughly x-shaped outline. The projecting calycular rim is strongly beaded and is often darker in color than the surrounding areas. The polyps do not form projecting verrucae, but retract flush across the calycular pit, and have the usual 8-rayed orifice at the center. The rind is exceedingly thin and contains few spicules, except between the longitudinal cortical solenia, each of which follows a groove in the axis. The cortex therefore appears to have lines of spicules running through it longitudinally. The siphonozooids occur as tiny verrucae between the lines of spicules in the cortex, i.e., along the solenia, especially basad from the autozooids.

The spicules are the same in both cortex and verrucae. There are two types, 8-radiates and numerous crosses. In the pharyngeal region and oral disk of the anthocodiae there are the usual minute, irregular rodlets and crosses.

The colonies are pale pink or salmon pink in color, the region surrounding the autozooids darker. Since the twig tips bear several calyces, they are customarily darker than the rest of the axis. The spicules are pink by reflected light.

HOLOTYPE: U.S.N.M. No. 49331. Pailolo Channel: Mokuhooniki Islet bearing North 35° West, 3.1 miles distant; depth 130-151 fathoms; coral, sand, shell, foraminiferans; bottom temperature 61° F. "Albatross" station 4100, July 23, 1902.

RECORDS: South coast of Molokai: Lae-o Ka Laau Light bearing North 74°30' West, 8.1 miles distant; depth 92-212 fathoms; fine gray-brown sand; bottom temperature 67° F. "Albatross" station 3838, April 4, 1902.

Pailolo Channel: Mokuhooniki Islet bearing North 31° West, 2.7 miles distant; depth 127-154 fathoms; broken coral, coarse gravel, rock; bottom temperature 60-61° F. "Albatross" station 3863, April 10, 1902.

Pailolo Channel: Mokuhooniki Islet bearing North 27° West, 3.3 miles distant; depth 136-148 fathoms; sand and pebbles; bottom temperature 64.8° F. "Albatross" station 3885, April 17, 1902.

West coast of Hawaii: Kawaihae Light bearing North 82°30' East, 4.1 miles distant; depth 198-147 fathoms; coral, sand, foraminiferans; bottom temperature 49° F. "Albatross" station 4045, July 11, 1902.

REMARKS: The largest specimens are about three inches high. Although the branching is mainly in one plane, twigs here and there grow out in various directions. The branches are twisted and tortuous with numerous swellings, cysts, tunnels and other deformities caused by the many epizooic and commensal animals that infest it. All specimens of *Corallium tortuosum* that I have examined are infested with a small zoanthid which pits and distorts the axis. The depressions caused by the zoanthid are distinguishable from those formed by the polyps of the *Corallium* itself

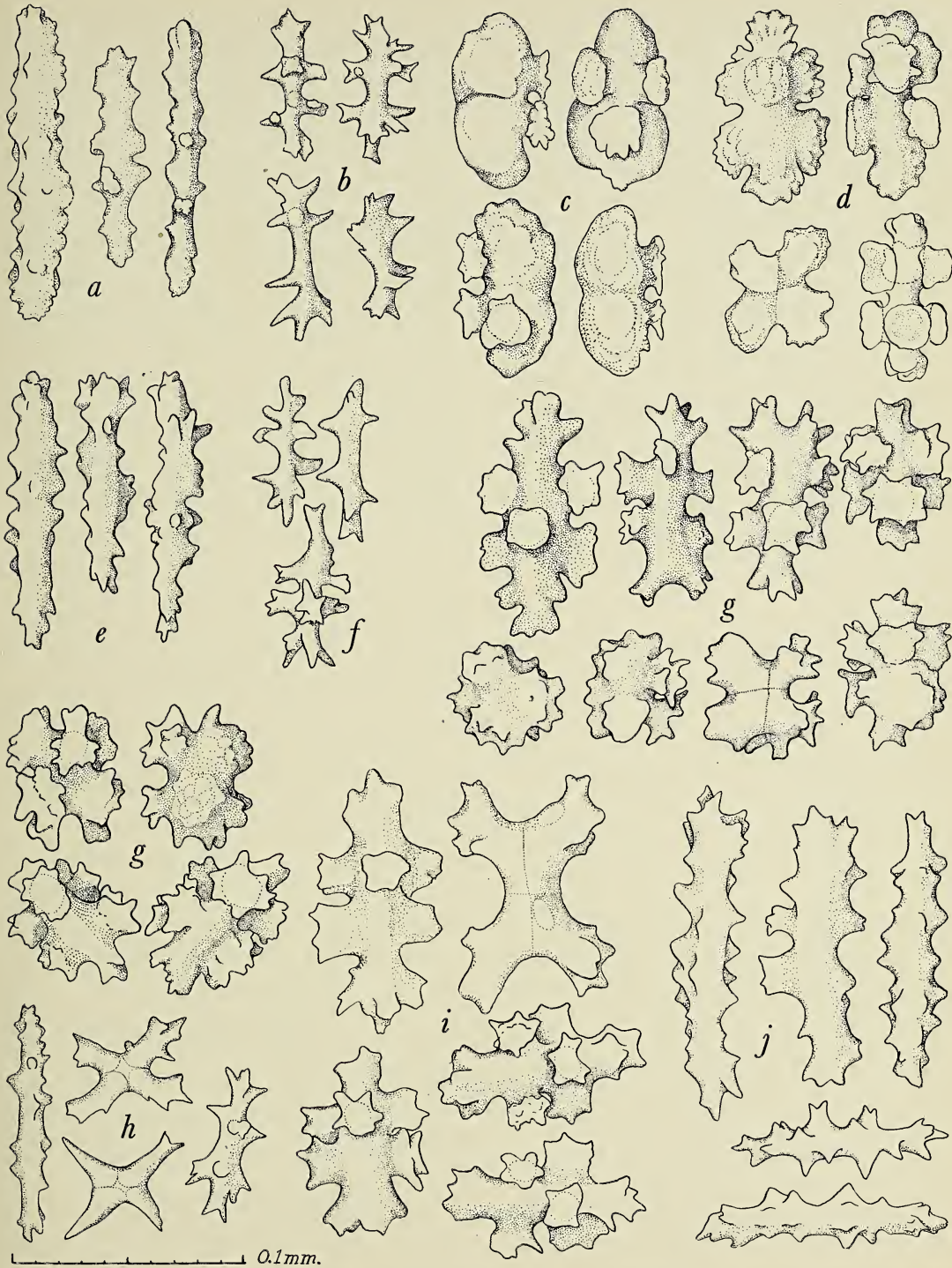


FIG. 7. Spicules of *Corallium* spp. a-d, *C. abyssale* sp. nov.: a, Verrucal spindles; b, spinose rods of pharyngeal region; c, double clubs of cortex; d, cross and 8-radiates of cortex. e-g, *C. regale* sp. nov.: e, Verrucal spindles; f, spinose rods of pharyngeal region; g, 6-, 7-, and 8-radiates, double clubs of cortex. h-j, *C. laauense* sp. nov.: h, Of pharyngeal region; i, 8-radiates and cross of cortex; j, verrucal spindles. Magnification of same for all figures.



by their larger size and lack of raised, beaded margin. The coral is also host to a polynoid polychaete, to which the tunnels and cavities in the axis are due. One specimen has in the main stem some chambers filled with a sponge, which may either be directly responsible for the cavities or merely occupying space left by some other inhabitant.

The Japanese *Corallium inutile* is similarly infested with actinians but, according to Kishinouye (1904: 19), the axis is not affected.

*Corallium stylasteroides* Ridley, 1882, is very similar in general appearance to *C. tortuosum*, but lacks the numerous cruciform spicules so conspicuous in the Hawaiian material.

*Corallium tortuosum* appears to be the most abundant precious coral in Hawaiian waters but, due to its small size and usually deformed axis, it probably has no commercial possibilities.

*Corallium niveum* sp. nov.

Fig: 5g; 8b-j

DIAGNOSIS: Colonies irregularly branched in one plane. Autozoid verrucae low, in groups, on front of colony only. Rind thick, not papillate. Spicules: 6-, 7-, and 8-radiates, crosses and double clubs, in verrucae and rind alike.

DESCRIPTION: The colonies are irregularly branched in one plane, the major branches often diverging strongly from near the base. The axis is solid, round, or oval, and longitudinally grooved; it is not pitted by the autozooids. The branches are stout, the largest ones 5-10 mm. in diameter at the base, tapering to about 2 mm. toward the tips, which are clavate. The autozooids form rather large, hemispherical verrucae with 8-rayed orifices, clustered in groups occurring almost exclusively on the front face of the colony. Each twig tip ends in a cluster of autozooids and thus assumes a clavate form. Small twigs arise from the front of the colonies, each ending in a recurved cluster of polyps which

is directed toward the base of the colony. The siphonozooids are inconspicuous, appearing as simple pores in the thick rind. The surface of the rind is finely wrinkled or corrugated, but bears no papillae.

The spicules of both verrucae and cortex are 6-, 7-, and 8-radiates, crosses and double clubs. In the pharyngeal region and oral disk of the polyps there are small spiny rods and crosses.

The rind and axis both are white; the spicules are colorless.

HOLOTYPE: U.S.N.M. No. 49328. Pailolo Channel: Mokuhooniki Islet bearing North 31° West, 2.7 miles distant; depth 127-154 fathoms; broken coral, coarse gravel, rock; bottom temperature 60°-61° F. "Albatross" station 3863, April 10, 1902.

RECORD: Pailolo Channel: Mokuhooniki Islet bearing North 35° West, 3.1 miles distant; 130-151 fathoms; coral, sand, shell, foraminiferans; bottom temperature 61° F. "Albatross" station 4100, July 23, 1902.

REMARKS: *Corallium niveum* is related to *C. pusillum* Kishinouye, from Japan, which differs in lacking the 6- and 7-radiate spicules and in its orange color.

Family ANTHOTHELIDAE

DIAGNOSIS: Monomorphic Scleraxonia with the cortex separated from the medulla by a circle of boundary canals. Medulla but rarely perforated by solenia in the branch tips. Gastric cavities of polyps reaching to medulla but not penetrating it.

This family has been divided into three subfamilies, of which only the typical one has been reported from Hawaiian waters.

Subfamily ANTHOTHELINAE

DIAGNOSIS: Anthothelidae with elongate, pointed cortical sclerites; the medullar spicules not long needles; spindles of tentacle bases bent and often clavate. Polyps with cylindrical, projecting calyces.

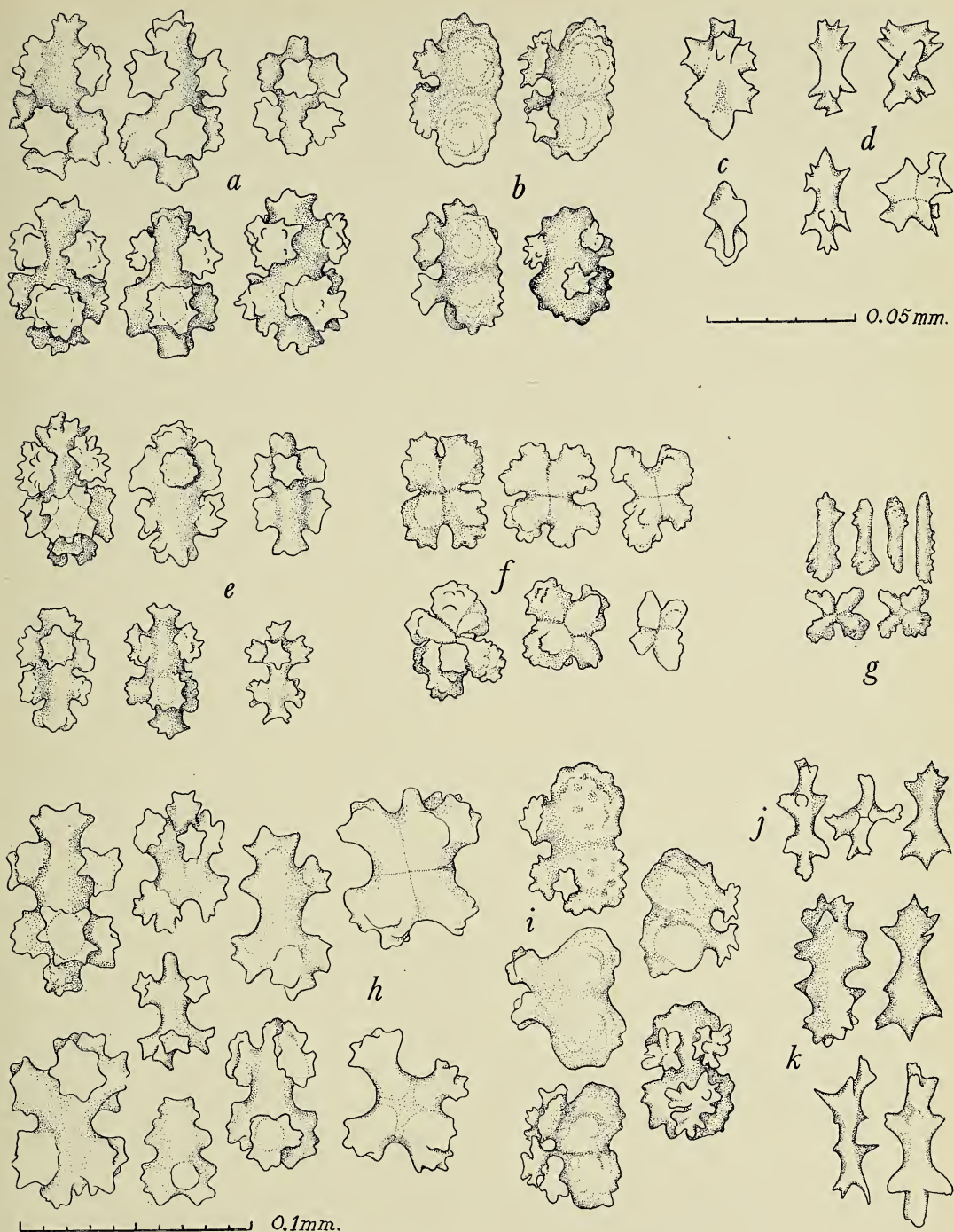


FIG. 8. Spicules of *Corallium* spp. a-d, *C. secundum* Dana: a, 8-radiates of cortex; b, double clubs; c, of tentacles; d, of pharyngeal region. e-g, *C. tortuosum* sp. nov.: e, 8-radiates and f, crosses, from cortex; g, of pharyngeal region. h-k, *C. niveum* sp. nov.: h, Crosses, 6-, 7-, and 8-radiates, and i, double clubs, of cortex; j, pharyngeals; k, pharyngeals at greater magnification. Scale at c and d applies also to k; scale at h to all others.



## Genus ANTHOTHELA Verrill

*Briareum* (pars) M. Sars, 1856, in: Sars, Koren and Danielssen, Faun. Litt. Norv., 2: 63.

?*Gymnosarca* Kent, 1870, Quart. Jour. Microscop. Sci. (2) 10: 397, pl. 21.

*Anthothela* Verrill, 1879, U. S. Natl. Mus., Proc. 2: 199. Verrill, 1883, Mus. Comp. Zool., Bul. 11: 40. Studer, 1887, Arch. Naturgesch. 53 Jahrg. Bd. 1: 28. Broch, 1912, Norske Selsk. Skr. 2: 4. Kükenthal, 1924, Tierreich 47: 14.

?*Stereogorgia* Kükenthal, 1916, Zool. Anz. 47: 178. Kükenthal, 1919, Tiefsee-Exped. 13 (2): 120. Kükenthal, 1924, Tierreich 47: 39.

DIAGNOSIS: As for the subfamily.

TYPE SPECIES: *Briareum grandiflorum* M. Sars, 1856 (by monotypy).

REMARKS: The colonies are usually ramose, arising from a membranous basal expansion, which may also produce polyps. The anthocodiae are at least partially retractile into the tubular calyces. The branches are usually tortuous and not infrequently anastomose. It is not unusual to find colonies (especially the Californian species) overgrown by sponges.

*Anthothela nuttingi* nom. nov.

Fig. 9a-e

*Clematissa alba* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 582, pl. 44, fig. 4; pl. 48, fig. 4.

*Muriceides alba* Kükenthal, 1924, Tierreich 47: 166.

Nec *Anthothela alba* Molander, 1929, Further Zool. Res. Swedish Antarct. Exped. 2 (3): 18.

DIAGNOSIS: Colony ramose; branches stout, clavate. Zooids on all sides; calyces tubular, not grooved. Transverse collaret and opercular points well-developed. Anthocodial spindles reaching 0.85 mm., clubs 0.65 mm.; thorny spindles of cortex up to 0.9 mm., less spiny rods up to 0.6 mm.; spiny rods and

spindles of medulla up to 1.2 mm., smooth rods 0.6+ mm.

DESCRIPTION: The loosely branched main stem is stout, 6.5 mm. in diameter at its thickest part; the branches taper from 3.5 mm. in diameter at their origins to 2.5 mm. just below the swollen tips. The medullar part of the stem near the base is perforated by solenia, which diminish and seem to disappear entirely toward the branch tips. A ring of boundary canals separates the cortex from the medullar region.

The polyps are irregularly placed on all sides of the stem and branches and are more crowded at the twig tips; the anthostoles are prominent, cylindrical, ungrooved calyces; the anthocodiae have a well-differentiated opercular armature containing numerous transverse collaret rows of slender spindles which merge without noticeable break into the eight *en chevron* tracts that form the opercular points. The latter contain large clubs 0.4-0.6+ mm. long, and thorny spindles reaching 0.75 mm. The thorny spindles of the rind reach 0.9 mm. in length, and the smoother rods about 0.6 mm. The spiny rods and spindles of the medullar region attain a length of 1.2 mm., and the practically smooth rods often exceed 0.6 mm. All spicules are colorless, and the colony is ivory white throughout.

HOLOTYPE: U.S.N.M. No. 25378. Center of Moku Manu (Bird Island) bearing South 77° 30' East, 11.1 miles distant; depth 762-1000 fathoms; white mud, foraminiferans, rock; bottom temperature 38° F.; "Albatross" station 4157, August 6, 7, 1902.

REMARKS: Molander (1929) has pointed out that Grieg's *Clavularia alba* is actually referable to *Anthothela*. This necessitates a new name for Nutting's "*Clematissa*" *alba*.

## Family MELITHAEIDAE

DIAGNOSIS: Monomorphic Scleraxonia with a jointed axis consisting of short nodes of horny matter with numerous rod-like spicules,



FIG. 9. *a-e*, *Anthothela nuttingi* nom. nov.: *a*, Anthocodial armature; *b-e*, spicules of cortex (*b*), medulla (*c*), anthocodia (*d*), anthocodia (*e*) (clubs). *f-j*, *Acabaria bicolor* (Nutting): Spicules of axis internodes (*f*), axis nodes (*g*), tentacles (*h*), operculum (*i*), cortex (*j*). Scale at *a* applies to that figure only; scale at *c* applies to *b-e*; scale at *j* applies to *f-j*.

and long internodes of fused spicules with little horny matter. Branching proceeds from the nodes.

REMARKS: The taxonomy of this exceedingly vexing group is badly in need of a thorough-going, modern revision. Until the

time when such a study is forthcoming, the student whose sorry fate it is to encounter melithaeids is referred to Hickson's memoir on the family (1937). The separation of genera, which is very difficult, may be facilitated by the following summary of characters as given by Hickson.



- a. Spicules at the surface of the coenenchym of various kinds. Blattkeulen and Stachelkeulen very rare or absent and when present few in number. Genus *Melitodes* (= *Melithaea*)
- b. Spicules at the surface mainly "birotulate" in form. Genus *Melitella*
- c. Numerous Blattkeulen and Stachelkeulen at the surface. Genus *Mopsella*
- d. Spicules at the surface mainly long spindles, a few Stachelkeulen present in some species. Genus *Acabaria*
- e. Spicules at the surface Blattkugeln forming a complete pavement-like protection for coenenchym and verrucae. Genus *Wrightella*
- f. Coenenchym comparatively thick, polyps small and capable of complete retraction into the coenenchym. Internodes of axis solid. Genus *Clathraria*

#### Genus ACABARIA Gray

*Acabaria* Gray, 1859, Zool. Soc. Lond., Proc.: 484. Hickson, 1937, Zool. Soc. Lond., Trans. 23 (3): 146. Hickson, 1940, Pub. Mar. Biol. Sta. Ghardaqa 2:4.

DIAGNOSIS: Melithaeidae with cortical spiculation consisting principally of spindles and clubs that are not broad leaf-clubs.

TYPE SPECIES: *Acabaria divaricata* Gray (by monotypy).

REMARKS: Hickson (1940, p. 4) gives the following definition of the genus:

Melitodidae with comparatively slender branches bearing, in the contracted condition, prominent verrucae. Many of the littoral species dwarf in size (40–50 mms.) and very variable in color and in the form of the corallum, others reaching a larger size (250 mms. or more in height) and flabellate in form with many anastomoses and uniformly red in color. The spicules are mainly spindles and clubs. In some species, but not in others, clubs with expanded spines at one end are found. These are known as Stachelkeulen (spiny clubs or foliaceous clubs).

#### *Acabaria bicolor* (Nutting)

Fig. 6a, b; 9f-j

?*Melitodes variabilis* Hickson, 1905, Fauna Geogr. Maldivae and Laccadive Arch. 2: 809, pl. 67, fig. 11. Thomson and Simpson, 1909, Alcyo. Investigator 2: 169.

*Verrucella bicolor* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 597, pl. 46, figs. 6, 7.

DESCRIPTION: The axis consists of alternating, spiculiferous horny nodes and calcareous internodes. The branching is dichotomous, not in one plane, and arises from the horny nodes. The polyps are retractile into dome-like calyces 1–1.25 mm. in diameter at the base, loosely arranged in a biserial manner and inclined toward one side of the branch, leaving the other side free of polyps. The rim of the calycinal aperture is distinctly 8-lobed. The anthocodiae are provided with a distinct operculum consisting of one or two rows of curved, thorny spindles transversely placed and eight radii of 2–3 pairs of slightly bent, thorny spindles set *en chevron* beneath the tentacles. The tentacles distally contain smaller, rod-like forms with conical spines. The cortex is filled mainly with rather spiny spindles; clubs with more or less foliate projections are less abundant than the spindles. The horny nodes are filled with small, belted rods, and the internodes with longer rods firmly cemented together. The calcareous axis is marked by deep longitudinal grooves.

The rind is pinkish orange, the crown and points bright orange and the remaining anthocodial spicules bright yellow. The axis is pink, the nodes brown.

HOLOTYPE: U.S.N.M. No. 25333. Kauai: Nawiliwili Light bearing North 86° West, 1.6 miles distant; 233–40 fathoms; coarse brown coral sand and shell; bottom temperature 48.5° F. (at the greatest depth); "Albatross" station 3982, June 10, 1902.

RECORD: Beach at Manana Island, off Oahu. C. E. Cutress, March, 1955.

REMARKS: Nutting's type of *Verrucella bicolor* consists of only a few terminal branches, but is sufficient to establish beyond a doubt that it is not a member of *Verrucella*. Nutting completely overlooked the principal diagnostic features of the specimen, which are obvious without removing it from the bottle. The spicules, moreover, do not even remotely resemble those of *Verrucella*.

The specimen collected by C. E. Cutress was found thrown up on the beach and thus probably lived in quite shallow water. It agrees in most regards with the type of *bicolor*, but is darker red in color. The colony is a low, dichotomously branched bush. Although not branched in one plane, the polyps all incline toward one side of the colony, leaving the opposite surface bare.

Family KEROEIDIDAE

DIAGNOSIS: "Colony erect; axis rigid, consisting of a central cord and of a cortical layer composed of smooth spicules conglomerated together by a horny matrix; Axenepithel remaining only at the tip of branches; polyps retractile into more or less well-developed calyces; spicules not scaly."

REMARKS: To the above diagnosis, taken from Kinoshita (1910), I would add: central chord of axis chambered; spicules of outer rind as thick spindles, irregularly tuberculate, or thick plates; in the anthocodiae, small bifurcate spicules shaped like crutches.

Genus KEROEIDES Studer

*Keroeides* Studer, 1887, Arch. Naturgesch., 53 Jahrg. Bd. 1: 30. Wright and Studer, 1889, Challenger Zool. 31 (1): 168. Kinoshita, 1910, Annot. Zool. Japon. 8 (4): 225. Stiasny, 1937, Siboga Exped. Monog. 13b<sup>8</sup>: 113.

This genus is easily recognized by its spiculiferous "scleraxonian" axis which, however, is penetrated by a chambered central chord.

*Keroeides* so perfectly bridges the gap between Scleraxonia and Holaxonia that its placement in the present system is difficult. For the sake of convenience, I am treating it in the same part of this report along with the scleraxonians. Its chambered axial chord points conclusively to its holaxonian affinities, and Kinoshita was unquestionably correct when he stated that *Keroeides* is no scleraxonian.

TYPE SPECIES: *Keroeides koreni* Wright and Studer, by subsequent monotypy, the first species being assigned by Wright and Studer, 1889.

The species known from, or likely to be found in, Hawaiian waters may be separated by the following key.

- 1. Superficial spicules as closely set large plates like paving stones.....*mosaica* sp. nov.
- 1. Superficial spicules as smaller spindles or elongate plates.....2
- 2. Colonies unbranched or very sparingly branched.....*fallax* sp. nov.
- 2. Colonies profusely branched in one plane.....3
- 3. Calyces small, usually 1 mm. or less in width at the base and 0.5–0.75 mm. in height, blunt conical; branches slender, end-twigs about 0.5 mm. in diameter; superficial spicules all rather large, pointed spindles. Bright red.....*koreni* Wright and Studer
- 3. Calyces larger, often 2.5 mm. in width at the base and 1.5–2.0 mm. in height, cylindrical or very slightly tapered; branches robust, end-twigs 1.0–1.5 mm. in diameter; superficial spicules large spindles interspersed with smaller, slender spindles. White or yellowish.....*pallida* Hiles

*Keroeides mosaica* sp. nov.  
Fig. 10a–f

DIAGNOSIS: Rind with large, closely fitting, polygonal, pavement-like plates. Twigs stiff;



branching lateral. Tentacular crutches 0.06–0.08 mm. long. White.

DESCRIPTION: The branching is lateral and apparently in one plane but the type is too fragmentary to demonstrate the overall pattern. The branches are rather stiff, bending upward, about 2 mm. in diameter and not noticeably tapering. The polyps are arranged in single rows bilaterally along the branches, either alternate or opposite; an occasional individual faces more toward one side or the other. The calyces are low and dome-like, the younger ones scarcely projecting above the general surface of the rind. The anthocodiae are fully retractile within the calyces.

The spicules of the outer rind are large, rounded or polygonal plates up to 3 mm. in length and 1.5 mm. in width, closely fitted as in mosaic. The plates near the verrucal margin become more elongate and merge into the warted spindles of the anthocodiae. In the tentacles there are small spinose rods, and crutch-shaped spicules 0.06–0.08 mm. long; the gullet has small spindles. The major sclerites are milky white, the smaller forms quite clear and colorless. The axis is made up of smooth, terete spindles closely bound together by a horny matrix; there is a chambered central chord. The axis is light brown in color, due to the horny material.

HOLOTYPE: U.S.N.M. No. 49336. Off Molokai: Lae-o Ka Laau Light bearing North 74° 30' West, 8.1 miles distant; depth 92–212 fathoms; fine gray-brown sand; bottom temperature 67° F. (reading probably made in shallow water at beginning of drag); "Albatross" station 3838, April 4, 1902.

REMARKS: This very distinct species bears a strong superficial resemblance to certain of the species of the holaxonian genus *Paracis*, but its spicular axis immediately distinguishes it.

*Keroeides fallax* sp. nov.

Fig. 11a–d

*Muricella tenera* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 586.

Nec *Muricella tenera* Ridley, 1884, Zool. Coll. H.M.S. "Alert": 335.

DIAGNOSIS: Sparingly branched: simple or once-forked. Calyces tall. Outer rind with thick spindles. Tentacular crutches 0.15–0.17 mm. long. Color, cream white (alcohol).

DESCRIPTION: The colonies are ordinarily only once bifurcate and often are simple, arising from a disk-like base attached to stones or shells. The stem is about 2.5 mm. in diameter and tapers to 1.0 mm. in the smallest part of the twigs. The polyps are set in the biserial arrangement typical of the genus, with an occasional individual out of line as is usual in the other species. They are well separated, often 10 mm. or more apart; the calyces are tall and nearly cylindrical, slightly tapered distally, about 2 mm. in diameter at the base and 1.5 mm. high. The anthocodiae usually remain exsert, though the tentacles are folded tightly inward.

The spicules of the rind are large, blunt, somewhat flattened spindles densely packed together. Spindles of the verrucae smaller, longitudinally arranged, merging with the spicules of the anthocodial wall, which are spinose rods. In the tentacles are curved rods and "crutches," the latter being much larger than those of *K. mosaica*, reaching a length of 0.17 mm. The spicules of the axis are smooth, terete spindles, occasionally fused together, set in a horny matrix. In the walls of the long gullet there are many sharply pointed spinose spindles of small size.

In alcohol, the colonies are creamy white; the axis is light brown.

HOLOTYPE: U.S.N.M. No. 49337. South coast of Molokai: Mokuhooniki Islet bearing North 46°45' East, 12 miles distant; depth 134–130 fathoms; sand, shell, and rock; bottom temperature 69.7° F.; "Albatross" station 3854, April 9, 1902.

RECORD: Off Molokai: Lae-o Ka Laau Light bearing North 74°30' West, 8.1 miles distant; depth 92–212 fathoms; fine gray-

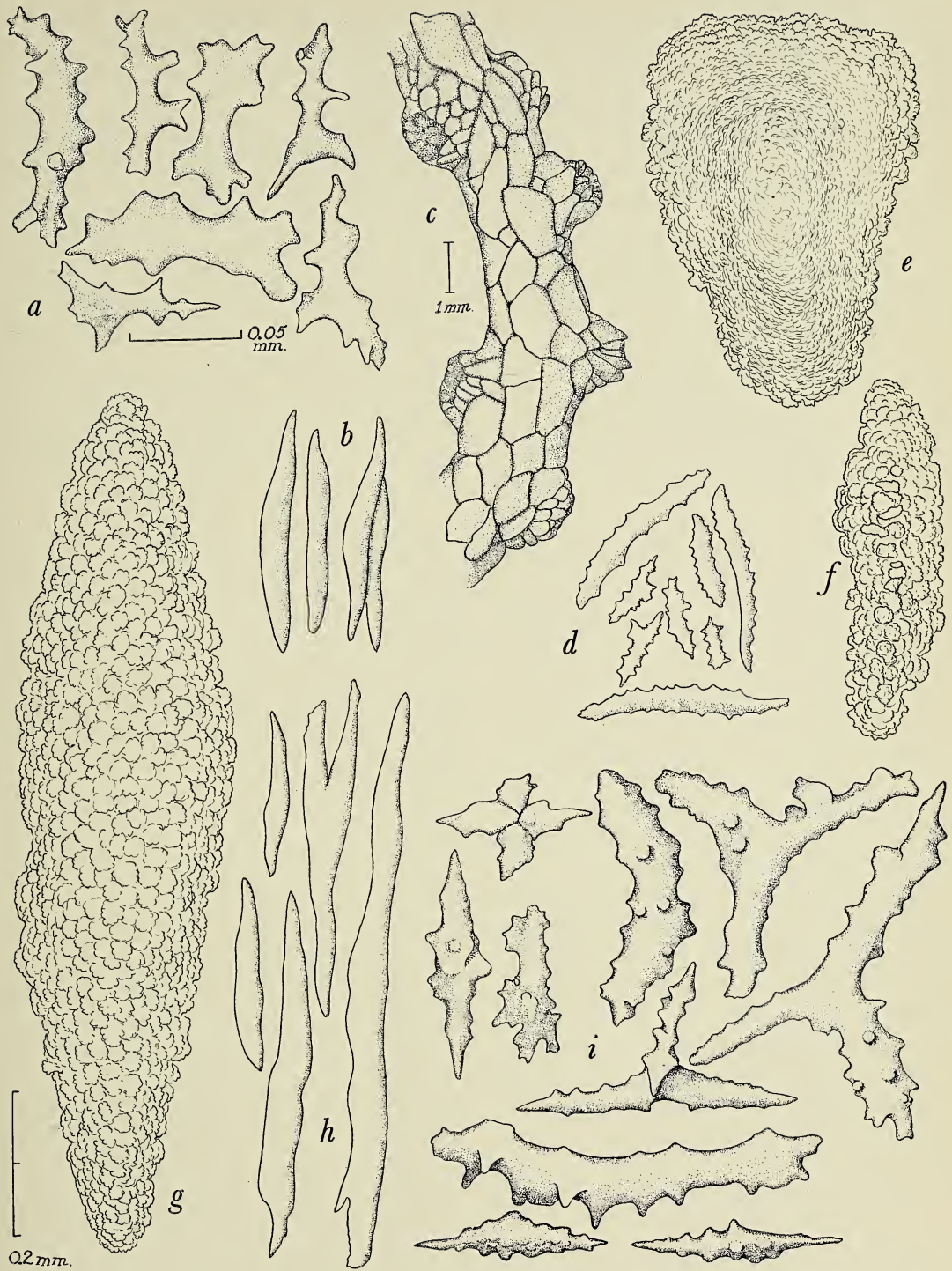


FIG. 10. *a-f*, *Keroeides mosaica* sp. nov.: *a*, Spicules of tentacles; *b*, spindles of axis; *c*, part of branch; *d*, flat rods from tentacles; *e-f*, smaller plates from rind. *g-i*, *Keroeides pallida* Hiles: Spicules of cortex surface (*g*), axis (*b*), anthocodia (*i*), including tentacular crutches. Scale at *a* applies to *a* and *i*; *c*, to *c* only; *g*, to all others.



brown sand; bottom temperature 67° F. (probably at shallow end of drag); "Albatross" station 3838, April 4, 1902.

**Keroeides koreni** Wright and Studer

Fig. 11e-g

*Keroeides koreni* Wright and Studer, 1889, Challenger Zool. 31 (1): 169, pl. 40, fig. 3. Kinoshita, 1910, Annot. Zool. Japon. 8 (4): 225. Bayer, 1949, Pacific Sci. 3 (3): 198. pl. 3, fig. 3.

DIAGNOSIS: Profusely branched in one plane, flabellate. Calyces small, subconical, projecting. Rind with blunt spindles, sometimes bent. Tentacular crutches up to 0.1 mm. long, often with several branches at one end. Red.

DESCRIPTION: The colonies are richly branched in one plane, rarely anastomosing or not at all; flabellate. The twigs are slender, about 0.5 mm. in diameter. The calyces are small, 1.0 mm. or less in diameter at the base and 0.5–0.75 mm. in height, subconical, and arranged in the usual biserial fashion.

The rind spicules are large, more or less flattened spindles often blunt and oval in outline. The tentacles have spiny rods, often curved, and the usual crutch- or Y-shaped spicules. The crutches measure 0.07–0.1 mm. in length. The gullet contains small, pointed spindles with rude sculpture. The spicules of the axis are long, occasionally fused together, quite smooth and terete.

The colony in alcohol is bright red.

REMARKS: Although *Keroeides koreni* is known from the Marshall Islands it has not yet been reported from the Hawaiian Islands, but it may well occur there.

**Keroeides pallida** Hiles

Fig. 10g-i

*Keroeides pallida* Hiles, 1899, Willey's Zool. Res. 2: 201, pl. 22, figs. 12–16.

*Keroeides gracilis* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 569.

Nec *Keroeides gracilis* Whitelegge, 1897, Austral. Mus., Mem. 3: 308, pl. 16, figs. 1–5. *Paramuricea aequatorialis* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 580.

Nec *Paramuricea aequatorialis* Wright and Studer, 1889, Challenger Zool. 31 (1): 100, pl. 22, fig. 6; pl. 26, fig. 3.

*Clematissa verrilli* Nutting, 1908, U. S. Natl. Mus., Proc. 34: 584.

Nec *Clematissa verrilli* Wright and Studer, 1889, Challenger Zool. 31 (1): 107, pl. 22, fig. 10; pl. 26, fig. 6.

DIAGNOSIS: Colonies branched in one plane, flabellate. Calyces large and conspicuous. Rind with large spindles between which are many small spindles. Tentacular crutches 0.12–0.17 mm. long. Color, cream white.

DESCRIPTION: The robust colonies are branched in one plane and assume a flabellate form; the branches are rather stout, the end twigs measuring 1.0–1.5 mm. in diameter. The calyces are large, 2.0–2.5 mm. wide at the base and 1.5–2.0 mm. tall, cylindrical or slightly tapered, biserially arranged. The anthocodiae are usually withdrawn almost completely in preservation.

The spicules of the rind are large, blunt spindles with many smaller spindles filling up the spaces between them. The large spindles do not fit closely together as they do in *K. fallax*. The spindles of the calyces are obliquely oriented at the base, longitudinally toward the apex. The calycular spicules merge into the anthocodial armature, which consists of thorny rods set *en chevron* in the tentacle bases. In the tentacles there are also some large, Y-shaped crutches about 0.12–0.17 mm. long, which have a different shape from those of *K. fallax*. The spicules of the axis are smooth, rather crooked spindles, which often anastomose and fuse together.

RECORDS: South coast of Molokai: Mokuhooniki Islet bearing North 49°45' East, 12.6 miles distant; depth 115–134 fathoms; coarse sand and shell; bottom temperature 68.5° F.; "Albatross" station 3853, April 9, 1902.

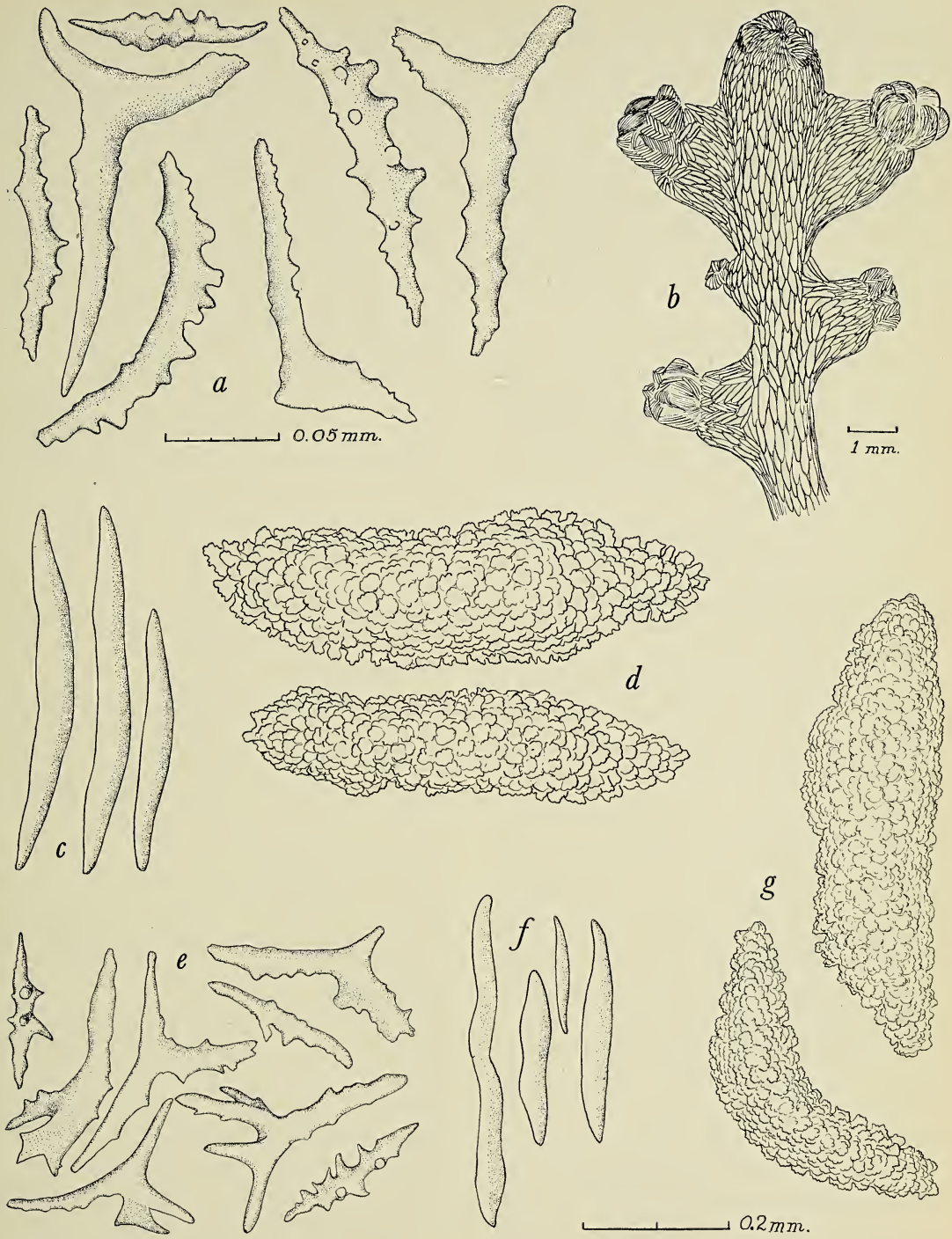


FIG. 11. *a-d*, *Keroeides fallax* sp. nov.: *a*, Tentacular crutches; *b*, branch tip; *c*, axial spicules; *d*, spindles of cortex. *e-g*, *Keroeides koreni* Wright and Studer: *e*, Tentacular crutches and pharyngeal rods; *f*, axial spindles; *g*, cortical spindles. Scale at *b* applies only to *b*; scale at *a* to *a* and *e*; scale at *g* to all others.



Pailolo Channel: Mokuhooniki Islet bearing North 18° East, 5.6 miles distant; depth 138–140 fathoms; fine sand and mud; bottom temperature 60.2°–60.5° F.; "Albatross" station 3859, April 9, 1902.

REMARKS: *Keroeides pallida* may be distinguished from *K. fallax* by its more profuse branching and coarser habit, by the small spindles clearly visible between the large sclerites, and by the form of its tentacular crutches.

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# A Translation of the Keys in the *Flora Micronesica* (1933) of Ryoza Kanehira

HAROLD ST. JOHN<sup>1</sup>

THE STANDARD BOOK on the botany of Micronesia is R. Kanehira's *Flora Micronesica* (1933). This was based on much new field work, careful study, and is a complete and profusely illustrated flora. Its usefulness to most botanists, however, is limited by the fact that it is printed wholly in Japanese characters. The writer has slowly and laboriously translated into English Kanehira's keys, all of which lead from the genera down to the species. It is a free translation, as a literal one would in places be unintelligible. In a few instances Kanehira's phrases are given in quotation marks and the translator's preferred version is given after it in brackets. Though inconsistent, the capitalization and spelling of the specific epithets follows that used by Kanehira (except for *Gymnosporia palanica*). Unfortunately it has been impossible to ask the collaboration of Kanehira, as he died in 1948.

The following translation is offered to the botanical public with confidence that it will supply a genuine need.

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PANDANUS

- (1)1. Fruit borne in clusters..... (2)  
2. Fruit borne singly..... (4)
- (2)1. Fruit ellipsoid, less than 6 cm. in diameter..... (3)

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Manuscript received May 31, 1955.

2. Fruit globose, more than 8 cm. in diameter..... **P. Kanehirae**
- (3)1. Fruit [cluster] flame-shaped, wrapped in leaf sheath [bracts]; small fruit [phalange] not conspicuously angled..... **P. aimiriikensis**
2. Fruit "spiral" [or cone- or shell-shaped], attached in a cluster, not enclosed in bracts; phalange with conspicuous angles..... **P. macrojeanneretia**
- (4)1. Phalange with one seed..... (5)  
2. Phalange many seeded..... (6)
- (5)1. Fruit globose, the diameter 30 cm....  
..... **P. dubius**
2. Fruit ellipsoid, scarlet when ripe, the diameter 13 cm..... **P. patina**
- (6)1. Phalange with summit jagged, the tips sharp pointed..... **P. duriocarpus**
2. Phalange with summit jagged, the tips not sharp pointed..... (7)
- (7)1. Phalange obconic, having 2-4 seeds, the summit not conspicuously jagged..... **P. kafu**
2. Phalanges numerous, 8-11-seeded, obovoid, the summit jagged.....  
..... **P. sinensis**

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FICUS

- (1)1. Flowers hidden in bottom of fruit by stipule-like scales..... (2)
2. Flowers hidden in bottom of fruit but without stipule-like scales..... (3)

- (2)1. Leaves long elliptic... **F. carolinensis**  
 2. Leaves elliptic, the apex emarginate...  
 ..... **F. retusa**  
 (3)1. Leaves cordate at base..... (4)  
 2. Leaves not cordate at base..... (5)  
 (4)1. Creeping vine; leaf venation pinnate,  
 not palmately 3-veined from the base  
 ..... **F. ramentacea**  
 2. Tall tree; leaves pinnately veined but  
 at base palmately 3-veined.....  
 ..... **F. Senffiana**  
 (5)1. Leaves ovate, at base rounded but  
 asymmetric..... **F. tinctoria**  
 2. Leaves broadly or narrowly elliptic...  
 ..... **F. philippinensis**

## Page 93 LAPORTEA

- (1)1. Leaves elongate perfect elliptic, 30 cm.  
 long..... **L. kusaiana**  
 2. Leaves ovate, 18 cm. long.....  
 ..... **L. saipanensis**

## Page 97 LORANTHUS

- (1)1. Leaves broad elliptic, gradually pointed,  
 hairy, 12 cm. long... **L. caudatifolius**  
 2. Leaves from oblong to ovate, 8 cm.  
 long..... **L. ponapensis**

## Page 98 PISONIA

- (1)1. Leaf obovate or long elliptic; inflores-  
 cence glabrous; fruit linear, 6 cm. long,  
 slippery, even..... **P. umbellifera**  
 2. Leaf ovate; inflorescence brown pu-  
 bescent; fruit 1–1.5 cm. long, lunate,  
 with the outer surface prickly.....  
 ..... **P. grandis**

## Page 109 HORSFIELDIA

- (1)1. Leaves chartaceous, lance-oblong, more  
 than 25–30 cm. long; fruit globose. (2)  
 2. Leaves coriaceous, oblong-lanceolate,  
 18 cm. long; fruit ellipsoid.....  
 ..... **H. palauensis**  
 (2)1. Fruit 1.5–1.8 cm. in diameter. **H. nunu**  
 2. Fruit 3–3.5 cm. in diameter.....  
 ..... **H. amklaal**

## Page 117 CINNAMOMUM

- (1)1. Leaves having petioles..... (2)  
 2. Leaves sessile..... **C. sessilifolium**  
 (2)1. Leaves ovate, the apex acuminate....  
 ..... **C. carolinense**  
 2. Leaves long elliptic-ovate, acute.....  
 ..... **C. carolinense** var. **oblongum**

## Page 124 PITTOSPORUM

- (1)1. Leaves "oblong" [= lanceolate], 16 cm.  
 long; flowers 11 mm. long; ovary  
 hairy..... **P. ponapense**  
 2. Leaves lanceolate, 10 cm. long; flowers  
 8 mm. long; ovary glabrous.....  
 ..... **P. kusaense**

## Page 127 PARINARIUM

- (1)1. Leaves long elliptic, 10–15 cm. long;  
 fruit 5–10 cm. in diameter.....  
 ..... **P. glaberrimum**  
 2. Leaves ovate or elongate ovate, 8–11  
 cm. long; fruit 1.5 cm. in diameter...  
 ..... **P. palauense**

## Page 133 CYNOMETRA

- (1)1. Leaflets 5–8 cm. long; petals 7 mm.  
 long; outer surface of fruit wrinkled..  
 ..... **C. carolinensis**  
 2. Leaflets as much as 11 cm. in length;  
 petals 11 mm. long; surface of fruit not  
 wrinkled..... **C. Yokotai**

## Page 148 SERIANTHES

- (1)1. Leaflets 12 mm. long, 5 mm. wide;  
 corolla tube 2 cm. long; pod 15 cm.  
 long, 5 cm. wide..... **S. grandiflora**  
 2. Leaflets 5 mm. long, 2 mm. wide;  
 corolla tube 12 cm. long; pod 12 cm.  
 long, 2.5 cm. wide..... **S. Nelsonii**

## Page 151 EVODIA

- (1)1. Leaflets less than 7–9 cm. long.....  
 ..... **E. nitida**  
 2. Leaflets more than 10 cm. long... (2)  
 (2)1. Flowers 6 mm. long; calyx lobes 1.5  
 mm. long..... **E. palawensis**



2. Flowers 1.5 cm. long; calyx lobes 7 mm. long. . . . . **E. trichantha**

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## AGLAIA

- (1)1. Shrubs; leaflets elongate obovate-elliptic, 2.5 cm. long; lateral veins 16 on a side. . . . . **A. palauensis**  
 2. Small trees; leaflets lance-oblong or broadly lanceolate, less than 20 cm. long; lateral veins 13 or less on a side. . . . . (2)  
 (2)1. Leaf elliptic; branches of inflorescence many; calyx lobes acute; fruit elliptic-orbicular. . . . . **A. mariannensis**  
 2. Leaf lance-oblong or broadly lanceolate; branches of inflorescence few; calyx lobes obtuse; fruit long obovoid. . . . . **A. ponapensis**

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## CLEISTANTHUS

- (1)1. Leaves 6–13 cm. long; fruiting capsule 8–15 mm. long. . . . . (2)  
 2. Leaves 15–22 cm. long; fruiting capsule 5 mm. long. . . . . **C. Morii**  
 (2)1. Lower surface of leaf brown; edges of the capsule rounded. . . . . **C. carolinensis**  
 2. Lower surface of leaf grayish white; edges of capsule ridged. **C. angularis**

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## MACARANGA

- (1)1. Leaves chartaceous, "ovate" [=round], 20 cm. long. . . . . **M. carolinensis**  
 2. Leaves coriaceous, round, 30 cm. long. . . . . **M. Thompsonii**

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## BUCHANANIA

- (1)1. Leaves elongate obovate, 10–15 cm. long, 6–8 cm. wide; fruit 1 cm. in diameter. . . . . **B. palawensis**  
 2. Leaves broadly obovate, 15–22 cm. long, 7–12 cm. wide; fruit 1.5 cm. in diameter. . . . . **B. Engleriana**

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## SEMECARPUS

- (1)1. Leaves oblanceolate, 100 cm. long; fruit reniform, 3 cm. long. . . . . **S. Kraemerii**

2. Leaves "lanceolate" [=narrowly oblanceolate], 40 cm. long; fruit globose, 2 cm. long. . . . . **S. venenosa**

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## GYMNOSPORIA

- (1)1. Leaves broad ovate, the apex rounded. . . . . **G. palauica**  
 2. Leaves ovate, the apex subobtuse. . . . . **G. Thompsonii**

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## ALLOPHYLLUS

- (1)1. Small trees; leaflets elliptic, less than 4.5 cm. wide, the margin entire. . . . . **A. holophyllus**  
 2. Shrubs, trees, or vines; leaflets ovate, more than 6 cm. wide, the margins coarsely serrate. . . . . (2)  
 (2)1. Spike longer than the leaves, few branched. . . . . **A. ternatus**  
 2. Spike shorter than the leaves, many branched. . . . . **A. timorensis**

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## ELAEOCARPUS

- (1)1. Leaves ovate or elliptic. . . . . (2)  
 2. Leaves lanceolate. . . . . (3)  
 (2)1. Leaves obovate or elliptic; fruit elliptic, more than 3 cm. in length. . . . . (4)  
 2. Leaves ovate; fruit less than 1.5 cm. in length. . . . . (5)  
 (3)1. Fruit elliptic, 2.5 cm. long. . . . . **E. carolinensis**  
 2. Fruit globose, 1.5 cm. long. . . . . **E. joga**  
 (4)1. Leaf base obtuse; fruit 4.5 cm. long. . . . . **E. kusaiensis**  
 2. Leaf base acute; fruit 3 cm. long. . . . . **E. rubidus**  
 (5)1. Leaves elliptic, 6–8 cm. long. . . . . **E. Kerstingianus**  
 2. Leaves ovate, 10–13 cm. long. . . . . **E. Kusanoi**

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## TRICHOSPERMUM

- (1)1. Branchlets stellate pubescent; leaves long ovate, 15 cm. long, lateral veins 6–7 on a side; flowers 2 cm. in diameter. . . . . **T. Ikutai**

2. Branchlets glabrous; leaves long elliptic, 10 cm. long, lateral veins 4-5 on a side; flowers 1 cm. in diameter. . . . .  
 . . . . . **T. Ledermannii**

Page 228 **HERITIERA**

- (1)1. Leaves long elliptic; petioles 2 cm. long; fruit skin thin. . . . **H. littoralis**  
 2. Leaves water-chestnut-shaped; petioles 4-6 cm. long; fruit skin thick. . . . .  
 . . . . . **H. longipetiolata**

Page 233 **CALOPHYLLUM**

- (1)1. Leaves 6-7 cm. long; fruit ellipsoid, 6-7 mm. long. . . . . **C. cholobtaches**  
 2. Leaves 10-15 cm. long; fruit globose, 3 cm. in diameter. . . . **C. Inophyllum**

Page 235 **GARCINIA**

- (1)1. Fruit globose, 3-4 cm. in diameter. . . . .  
 . . . . . **G. Matudai**  
 2. Fruit obovoid or long ellipsoid, less than 2 cm. in diameter. . . . . (2)  
 (2)1. Fruit long obovoid, 2 cm. in diameter, 3 cm. long. . . . . **G. rumiyo**  
 2. Fruit ellipsoid, 2 cm. long. . . . . (3)  
 (3)1. Leaves 7-8 cm. long, almost sessile. . . . .  
 . . . . . **G. ponapensis**  
 2. Leaves 12 cm. long; petioles 10-12 mm. long. . . . . **G. trukensis**

Page 241 **PENTAPHALANGIUM**

- (1)1. Leaves 20 cm. long; flowers 20 mm. in diameter; fruit 2 cm. long. . . . .  
 . . . . . **P. carolinense**  
 2. Leaves 15 cm. long; flowers 10 mm. in diameter; fruit 5 cm. long. . . . .  
 . . . . . **P. Volkensii**

Page 248 **THYMELAEACEAE**

- (1)1. Leaves 15-20 cm. long, 7-8 cm. wide; corolla tube white, 15 mm. long. . . . .  
 . . . . . **Phaleria Cumingii**  
 2. Leaves 12-17 cm. long, 5-6 cm. wide; corolla tube golden yellow, 24 mm. long. . . . . **Wikstroemia elliptica**

Page 252 **BARRINGTONIA**

- (1)1. Leaves obovate or long elliptic, 40 cm. long, 15-20 cm. wide; fruit 4-angled, the 4 sides of the body 10 cm. long. . . . .  
 . . . . . **B. asiatica**  
 2. Leaves long elliptic or oblanceolate, 30 cm. long, as much as 6-10 cm. wide; fruit long ellipsoid, 5-6 cm. long. . . . .  
 . . . . . **B. racemosa**

Page 257 **RHIZOPHORA**

- (1)1. Leaves "lance-oblong" [=narrowly elliptic]; flowers twinned, sessile [on the peduncle]. . . . . **R. apiculata**  
 2. Leaves elliptic; flowers mostly pedicelled in short cymes. . . **R. mucronata**

Page 262 **TERMINALIA**

- (1)1. Leaves long elliptic-obovate, as much as 50 cm. long; fruit ellipsoid, acute at both ends. . . . . **T. carolinensis**  
 2. Leaves obovate, 30 cm. long; fruit ellipsoid, flattened. . . . . **T. Catappa**

Page 265 **DECASPERMUM**

- (1)1. Leaves glabrous, oblong. . . . .  
 . . . . . **D. fruticosum**  
 2. Branchlets, petioles, and midrib of sepals silvery white hairy; leaves lanceolate. . . . . **D. Raymundi**

Page 267 **EUGENIA**

- (1)1. Leaf base cordate. . . . . (2)  
 2. Leaf base not cordate. . . . . (6)  
 (2)1. Leaf ovate. . . . . (3)  
 2. Leaf long elliptic. . . . . (4)  
 (3)1. Flowers in terminal corymbs. . . . .  
 . . . . . **E. Suzukii**  
 2. Flowers in axillary cymes. **E. javanica**  
 (4)1. Leaves 15-30 cm. long. . . . . (5)  
 2. Leaves 8-14 cm. long. . . . .  
 . . . . . **E. Thompsonii**  
 (5)1. Small twigs 4-angled and -winged. . . . .  
 . . . . . **E. stelechanthoides**  
 2. Small twigs terete, wingless. . . . .  
 . . . . . **E. stelechantha**



- (6)1. Leaves less than 8 cm. long..... (7)  
 2. Leaves more than 10 cm. long .... (8)  
 (7)1. Leaves long elliptic, acute at both ends  
 ..... **E. palumbis**  
 2. Leaves elliptic or obovate..... (9)  
 (8)1. Leaves more than 15 cm. long.....  
 ..... **E. malaccensis**  
 2. Leaves less than 12 cm. long... (10)  
 (9)1. Leaves elliptic; flowers mostly single  
 in the axils..... **E. Reinwardtiana**  
 2. Leaves obovate, obtuse; flowers in ter-  
 minal cymes..... **E. palauensis**  
 (10)1. Leaves pinnately veined.....  
 ..... **E. carolinensis**  
 2. Leaves parallel veined..... **E. cumini**

Page 278      **ASTRONIA**

- (1)1. Leaves long elliptic; inflorescence pen-  
 dent..... **A. ponapensis**  
 2. Leaves elliptic; inflorescence erect. (2)  
 (2)1. Leaf tip rounded [apiculate]; inflores-  
 cence a panicle; petals milky white...  
 ..... **A. palauensis**  
 2. Leaf tip acuminate; inflorescence a  
 cyme; petals yellow.. **A. carolinensis**

Page 282      **MEDINILLA**

- (1)1. Vine; leaves long elliptic.....  
 ..... **M. Blumeana**  
 2. Small shrub; leaves large, ovate, size  
 irregular..... **M. diversifolia**

Page 292      **POLYSCIAS**

- (1)1. Leaflets entire; inflorescence a panicle;  
 fruit flat, round..... **P. grandifolia**  
 2. Leaflets pubescent, coarsely serrate;  
 inflorescence of compound cymes;  
 fruit ovoid..... **P. subcapitata**

Page 294      **SCHEFFLERA**

- (1)1. Small trees; flowers erect, in "spikes"  
 [=racemose umbellets]. **S. pachyclada**  
 2. Vines; flowers in cymes... **S. odorata**

Page 298      **DISCOCALYX**

- (1)1. Leaves 25-35 cm. long. **D. ponapensis**  
 2. Leaves 15-25 cm. long. **D. megacarpa**

Page 299      **MAESA**

- (1)1. Leaves round or elliptic.....  
 ..... **M. palauensis**  
 2. Leaves obovate..... **M. carolinensis**

Page 300      **RAPANEA**

- (1)1. Leaves 5-11 cm. long.....  
 ..... **R. carolinensis**  
 2. Leaves 12-16 cm. long. **R. palauensis**

Page 307      **SIDEROXYLON**

- (1)1. Leaves 8-12 cm. long; seed 1.....  
 ..... **S. glomeratum**  
 2. Leaves 15-21 cm. long; seeds 2-3....  
 ..... **S. micronesicum**

Page 313      **COUTHOVIA**

- (1)1. Leaves broad ovate, the base obtuse;  
 lateral veins 6 to a side; fruit fusiform  
 ..... **C. calophylla**  
 2. Leaves obovate, the base cuneate; lat-  
 eral veins 9 to a side; fruit ellipsoid..  
 ..... **C. toua**

Page 316      **FAGRAEA**

- (1)1. Fruit ellipsoid..... **F. ksid**  
 2. Fruit globose..... (2)  
 (2)1. Leaves elliptic, obtuse, petioled.....  
 ..... **F. sair**  
 2. Leaves obovate, obtuse, subsessile...  
 ..... **F. galilai**

Page 319      **GENIOSTOMA**

- (1)1. Leaves sessile..... **G. sessile**  
 2. Leaves petioled..... (2)  
 (2)1. Ultimate branches of inflorescence  
 densely pubescent..... (3)  
 2. Ultimate branches of inflorescence  
 glabrous..... (4)  
 (3)1. Leaves 4-6 cm. long; calyx lobes acute,  
 3-angled..... **G. Hoeferi**  
 2. Leaves 6-8 cm. long; calyx lobes ob-  
 tuse, 3-angled..... **G. micranthum**  
 (4)1. Leaves long ovate, acute. **G. kusaiense**  
 2. Leaves lanceolate, subacuminate.....  
 ..... **G. stenurum**

## Page 325 ALYXIA

- (1)1. Leaves opposite, 4.5 cm. long; fruit 10 mm. long, 6 mm. in diameter. . . . . **A. palauensis**
2. Leaves whorled, 4–6 cm. long; fruit 13 mm. long, 8 mm. in diameter. . . . . **A. Torresiana**

## Page 327 CERBERA

- (1)1. Inflorescence a corymb; corolla scarlet, 1.5 cm. in diameter. . . . **C. floribunda**
2. Inflorescence a cyme; corolla white, 3 cm. in diameter. . . . . (2)
- (2)1. Calyx lobes long elliptic; corolla lobes asymmetric, 3-angled. . . . **C. dilatata**
2. Calyx lobes shallow; corolla lobes obovate. . . . . **C. Manghas**

## Page 332 RAUWOLFIA

- (1)1. Leaves elliptic; inflorescence longer than the leaves; flowers few. . . . . **R. laxiflora**
2. Leaves lanceolate; inflorescence short; flowers many. . . . . **R. insularis**

## Page 341 GMELINA

- (1)1. Scandent shrub; leaves elliptic, 10 cm. long. . . . . **G. elliptica**
2. Tall trees; leaves obovate or broad elliptic, 10–15 cm. long. . . . . **G. palawensis**

## Page 342 PREMNA

- (1)1. Small shrub; leaves cordate, 8–12 cm. long. . . . . **P. angustiflora**
2. Small tree; leaves elliptic, 10–12 cm. long. . . . . **P. gaudichaudii**

## Page 343 VITEX

- (1)1. Shrubs. . . . . **V. trifolia**
2. Tall trees. . . . . (2)
- (2)1. Leaves simple. . . . . **V. cofassus**
2. Leaves of 5 leaflets. . . . . **V. glabrata**

## Page 348 CYRTANDRA

- (1)1. Vines. . . . . **C. palawensis**
2. Small shrubs. . . . . (2)

- (2)1. Leaves long elliptic; petiole 7 cm. long; calyx lobes two, 3-angled. . . . . **C. rôdaiensis**
2. Leaves ovate or rhombic-elliptic; petiole less than 5 cm. long; calyx lobes 4, lanceolate. . . . . (3)
- (3)1. Leaves rhombic; calyx lobes 11 mm. long, the outer surface pubescent. . . . . **C. ponapensis**
2. Leaves ovate-elliptic; calyx lobes 18 mm. long, glabrous. . . . **C. Urvillei**

## Page 354 BIKKIA

- (1)1. Corolla lobes acute, as long as broad; calyx lobes linear. . . . **B. palauensis**
2. Corolla lobes obtuse, shorter than wide; calyx lobes with three pointed prongs. . . . . **B. mariannensis**

## Page 360 IXORA

- (1)1. Flowers 2–3, terminal. . . . **I. triantha**
2. Inflorescence umbellate, ball-like, or a compact tassel. . . . . (2)
- (2)1. Inflorescence ball-like, usually compact. . . . . **I. confertiflora**
2. Inflorescence an umbel, usually elongate. . . . . (3)
- (3)1. Leaves long elliptic, as much as 25 cm. in length. . . . . **I. pulcherrima**
2. Leaves lanceolate, 11 cm. long. . . . . **I. pulcherrima** var. **lanceolata**

## Page 364 MORINDA

- (1)1. Vines. . . . . (2)
2. Small trees. . . . . (3)
- (2)1. Large vines; leaves ovate, 7–9 cm. long. . . . . **M. glandulosa**
2. Small vines; leaves long elliptic-ovate, 10–13 cm. long. . . . . **M. volubilis**
- (3)1. Flower head with enlarged petals if any. . . . . **M. latibracteata**
2. Flower head without enlarged petals. . . . . (4)
- (4)1. Leaves long elliptic, 15–20 cm. long; flower head an elongate cluster. . . . . **M. pedunculata**



- 2. Leaves broad elliptic, 15–25 cm. long or more; flower head for the most part in a short cluster.....**M. citrifolia**

- 2. Leaves 12–16 cm. long; corolla tube 6 mm. long, the lobes obovate.....**T. sambucina**

Page 370      PSYCHOTRIA

- (1)1. Flowers terminal, in a long panicle; leaves more than 18 cm. long.....**P. rhombocarpa**
- 2. Flowers in a short terminal cyme or cluster; leaves less than 15 cm. long.....(2)
- (2)1. Flowers clustered.....**P. Merrillii**
- 2. Flowers in a short cyme.....(3)
- (3)1. Leaves long elliptic, acute at both ends.....**P. arbuscula**
- 2. Leaves obovate, the apex obtuse..(4)
- (4)1. Leaves coriaceous; lateral veins 6–8 on a side; corolla 6 mm. long.**P. mariana**
- 2. Leaves membranous; lateral veins 5 on a side; corolla 2.5 mm. long.....**P. rotensis**

Page 379      TARENNA

- (1)1. Leaves 7–10 cm. long; corolla tube 3 mm. long, the lobes long elliptic....**T. glabra**

Page 381      TIMONIUS

- (1)1. Leaf base auriculate or cordate....(2)
- 2. Leaf base not auriculate or cordate.(3)
- (2)1. Upper side of leaves pubescent.....**T. mollis**
- 2. Upper side of leaves smooth and glabrous.....(4)
- (3)1. Leaves with lower surface pubescent along midrib and lateral veins.....**T. ponapensis**
- 2. Leaves glabrous or slightly pubescent.....(5)
- (4)1. Leaves rhombic or elliptic.....**T. corymbosus**
- 2. Leaves ovate or elliptic.**T. subauritus**
- (5)1. Leaves long elliptic, 12–16 cm. long..**T. Ledermannii**
- 2. Leaves elliptic or obovate, 13 cm. long.....(6)
- (6)1. Fruit long, slender, commonly 6 mm. in diameter.....**T. korrense**
- 2. Fruit short, commonly 10 mm. in diameter.....**T. albus**

## A Report on the Poisonous Fishes Captured During the Woodrow G. Krieger Expedition to Cocos Island<sup>1</sup>

BRUCE W. HALSTEAD AND DONALD W. SCHALL<sup>2</sup>

THIS IS THE FOURTH of a series of epidemiological reports concerning the poisonous fishes of the tropical Pacific. The first report (Halstead and Bunker, 1954*a*) dealt with the Phoenix Islands, the second (Halstead and Bunker, 1954*b*) with Johnston Island, and the third (Halstead and Schall, 1955) with the Galápagos Islands. For a general résumé of the overall problem of poisonous fishes and ichthyosarcotoxism, the reader is referred to two earlier reports by the senior author (1951, 1953).

A more complete discussion of the manner in which fishes are believed to become poisonous has been published elsewhere (Halstead and Bunker, 1954*a*). There are probably a multiplicity of factors governing the degree of toxicity of a fish, viz., abundance of certain types of food, the availability of certain types of organic chemical constituents in that food, and the physiology of the fish.

Although numerous poisonous fish species are known to occur in the West Indies, Red Sea, and in various parts of the Pacific, a literature of more than 1500 publications on poisonous marine organisms is silent regarding the tropical Eastern Pacific. The basic

objective of this expedition was to determine if poisonous fishes occurred in this region, with the hope that the knowledge gained thereby would contribute directly to a better understanding of the origin and distribution of toxic fishes in the tropical Pacific. As there are no inhabitants at Cocos, it was not possible to appraise the practical importance of the poisonous fishes found.

The expedition to Cocos Island was made possible through the generosity of Mr. Woodrow G. Krieger, president of the Douglas Oil Company of California, and the Office of Naval Research, Department of the Navy. In addition to making his 96-foot yacht, the "Observer," available to the scientific party, Mr. Krieger also installed special laboratory and refrigeration facilities on his yacht to accommodate our group. Grateful acknowledgement is made for the invaluable contributions to our research program of both Mr. Krieger and the Office of Naval Research. With the exception of the family Scaridae, all of the fishes listed in this report were identified by Dr. Boyd Walker of the Department of Zoology, University of California at Los Angeles. Dr. Leonard P. Schultz of the U. S. National Museum identified the scarids. Our sincere appreciation is expressed to these individuals for their valuable contributions to this report. The scientific party included Norman C. Bunker, Jeanne M. Bunker, Leonard S. Kuninobu, Donald G. Ollis, and the senior author. The "Observer" departed from Newport Bay, California, on December 3, 1952,

<sup>1</sup> This investigation was supported by a research grant from the Division of Research Grants and Fellowships, National Institutes of Health, Public Health Service, and a contract from the Office of Naval Research, Department of the Navy (Contract No. NONR-205). Manuscript received January 14, 1955.

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and proceeded to Punta Arenas, Costa Rica, and thence to Cocos Island.

#### GEOGRAPHY AND ECOLOGY OF COCOS ISLAND

Cocos Island is located at lat.  $5^{\circ}22'N.$ , long.  $87^{\circ}04'W.$ , (Hydrog. Off. 1951, Freeman 1951, Robson 1950, Chubb 1933) about 540 miles southwest of Panama. The island is 4 miles long by 2 miles wide. There are four peaks or hills, the highest of which rises to an altitude of 1,932 feet (Hydrog. Off., 1951; Chubb 1933, gives an altitude of 2,788 feet). From the main peak the ground slopes gradually to the summit of cliffs at a height of about 600 feet above sea level. The island is volcanic in origin and has a very irregular shore line obstructed by islets, rocks and shoal areas which may extend as much as one-half mile offshore. There are two principal bays or anchorages, Wafer and Chatham Bays, both of which are located on the northern side of the island. The water immediately surrounding the island is relatively shallow, ranging in depth from  $\frac{1}{4}$  to 20 fathoms within 200 to 1,000 meters from the shore. The bottom at Chatham Bay, the area from which most of our Cocos Island specimens were taken, is of sand and large boulders. No coral reefs were observed. The surrounding water is clear, and the surface temperature at the time of our visit was  $27^{\circ}C$ . The extreme annual range is said to be about  $5.5^{\circ}C$ . A pounding surf about most of the island, except for some of the protected bays, makes boat landing a hazardous procedure.

The island has frequent torrential rains, luxuriant vegetation and an almost impenetrable jungle. Fresh-water streams and waterfalls are numerous. There is no human population at present. Wild goats were observed to be abundant. Hogs and rats are also reported to be present. Oceanic birds of various kinds are present in large numbers.

Collecting conditions at Chatham Bay were excellent for spear fishing, considerably better than any of the areas subsequently visited during the trip. White-tipped sharks, *Triae-*

*nodon obesus*, were found to be exceedingly abundant, but innocuous to skin divers. Various other species of shark were observed. Puffers, *Arothron setosus*, were present in large numbers. Fishes such as rainbow runners, jacks, triggerfish, filefish, surgeonfish, squirrelfish, blennies, butterflyfish, snappers, macerels, half beaks, groupers, parrotfish, moray eels, trumpetfish, wahoo, skipjacks, yellowfin tunas, sailfish, were common.

#### MATERIALS AND METHODS

##### *Collection of Fishes*

The fish specimens were collected with the use of rotenone, spear, dynamite or dip net. Within a short time after collection the smaller specimens were sorted, labeled, placed in plastic bags according to the station from which they were taken, and frozen in a deep freeze unit. In the case of the larger specimens, samples were taken from the muscle, liver, intestines, and gonads in the field. An identification number was assigned to the tissue sample and a duplicate number given to the dissected fish which was then placed in a barrel of 10 per cent formalin for future taxonomic purposes. The frozen material remained in that condition until tested in the laboratory. A considerable amount of ecological data was accumulated at each station and may be obtained from the authors. The stations from which the specimens used in this study were taken are K 52—10 to 15, 17 to 19, 21 to 22 (see Fig. 1).

##### *Methods Used in Screening Fishes*

Fishes were screened by preparing, whenever possible, aqueous extracts of muscle, liver, intestines, and gonads of each specimen. Four laboratory white mice were used for testing each extract. One ml. of the extract was used for each mouse. The mice were observed for a period of 36 hours and then classified as negative, weakly, moderately or strongly positive on the basis of symptoms developed. For details concerning the tech-

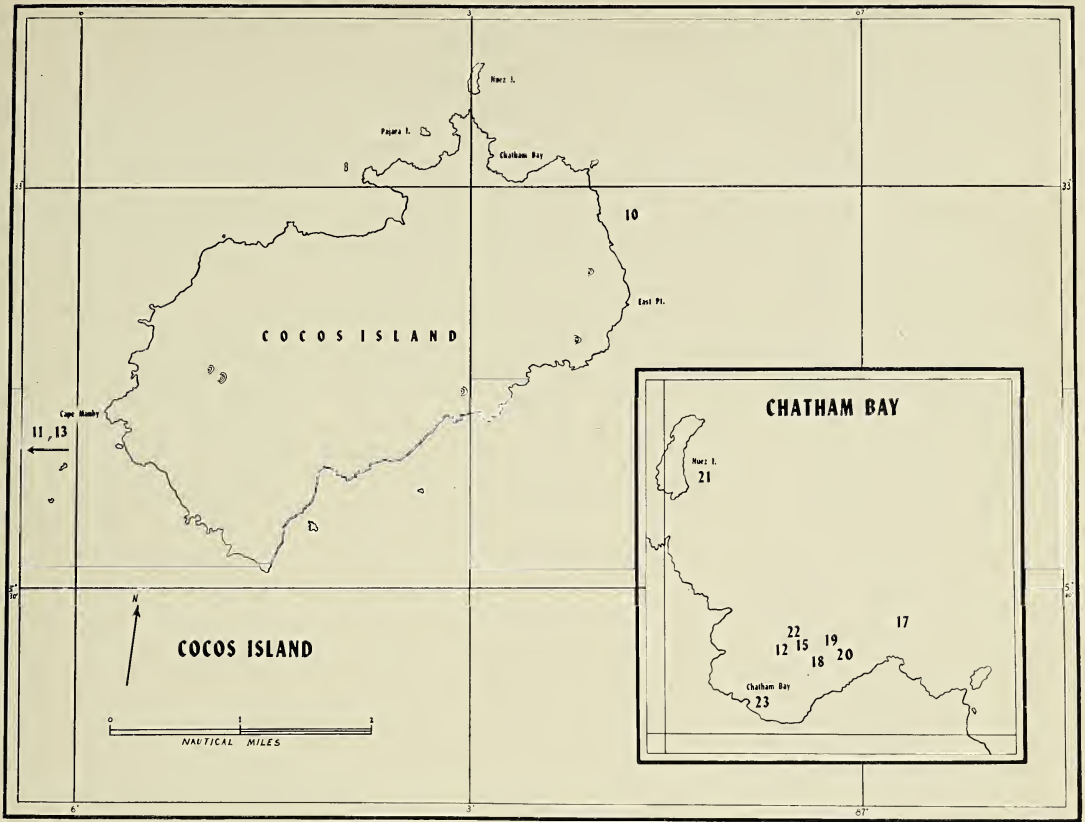


FIG. 1. Map of Cocos Island showing the locations (numbers 10–15, 17–19, 21, 22) at which specimens were collected.

niques used in testing for ichthyosarcotoxins see Halstead and Bunker (1954a).

#### *Terminology Used Concerning Degrees of Toxicity*

The classification used is an arbitrary one which gives some idea as to the degree of toxicity of a fish species within a particular geographical area. This method makes no attempt to differentiate between virulence and concentration. Moreover, the interpretation of *weakly positive* results in terms of human symptomatology is not clearly understood at this time. Hence, the reader is cautioned about arriving at hasty conclusions regarding the results of this study. The categories used are:

1. *Negative*—the test is negative if the

mouse continues to remain asymptomatic during the maximum test period of 36 hours, or dies after that time.

2. *Weakly positive*—the test is weakly positive if the mouse shows definite symptoms such as lacrimation, diarrhea, ruffling of the hair, hypoactivity, ataxia, etc., but *recovers*.

3. *Moderately positive*—this term is used if the mouse develops hypoactivity, ruffling of the hair, lacrimation, diarrhea, paralysis, etc., and *dies within a period of 1 to 36 hours*.

4. *Strongly positive*—if the mouse develops hypoactivity, ataxia and paralysis which is usually followed by clonic or tonic convulsions of varying degrees, paradoxical respiration, respiratory paralysis, and *death occurs within a few seconds to one hour*.



TABLE 1

AN ANALYSIS OF COCOS ISLAND FISHES WITH REFERENCE TO THEIR TOXICITY  
(Each specimen examined is listed separately)

FISH TESTED	EXTRACT TESTED*					
	Muscle	Liver	Gonads	Intestine	Viscera	Intestinal Content
<b>ACANTHURIDAE—Surgeonfish</b>						
<i>Acanthurus aliala</i> Lesson.....	—				—	
<i>Acanthurus aliala</i> Lesson.....	—			W		
<i>Acanthurus crestonis</i> (Jordan and Starks).....	—	—	—	—		
<i>Acanthurus crestonis</i> (Jordan and Starks).....	M				M	
<i>Ctenochaetus strigosus</i> (Bennett).....	—				M	
<b>ALUTERIDAE—Filefish</b>						
<i>Alutera monoceros</i> Linnaeus.....	—	—		—		
<i>Alutera monoceros</i> Linnaeus.....	—	M	—	—		
<i>Alutera monoceros</i> Linnaeus.....	—	—		M		
<i>Alutera monoceros</i> Linnaeus.....	—	—		M		
<b>BALISTIDAE—Triggerfish</b>						
<i>Balistes verres</i> Gilbert and Starks.....	—				—	
<i>Balistes verres</i> Gilbert and Starks.....	—	—			—	
<i>Balistes verres</i> Gilbert and Starks.....	—				—	
<i>Balistes verres</i> Gilbert and Starks.....	W				—	
<i>Balistes verres</i> Gilbert and Starks.....	—	—		—		
<i>Balistes verres</i> Gilbert and Starks.....	—	—	—			
<i>Balistes verres</i> Gilbert and Starks.....	—	—		W		
<i>Balistes verres</i> Gilbert and Starks.....	—	—	—	—		
<i>Melichthys radula</i> (Solander).....	—	—	—	—		
<i>Melichthys radula</i> (Solander).....	—	—	—	—		
<i>Melichthys radula</i> (Solander).....	—	—	—	—		
<i>Melichthys radula</i> (Solander).....	—	W	—	M		
<i>Melichthys radula</i> (Solander).....	—	—	—	—		
<i>Melichthys radula</i> (Solander).....	—	—	—	—		
<i>Melichthys radula</i> (Solander).....	—	W	—	—		
<i>Melichthys radula</i> (Solander).....	—				—	
<b>CARANGIDAE—Pompano, Jacks</b>						
<i>Caranx caballus</i> Günther.....	M		W	M		
<i>Caranx melampygus</i> Cuvier and Valenciennes.....	—	—	—			
<i>Caranx melampygus</i> Cuvier and Valenciennes.....	—	—	—	W		
<i>Caranx melampygus</i> Cuvier and Valenciennes.....	W	—		—		
<i>Elagatis bipinnulatus</i> (Quoy and Gaimard).....	—	—	—	—		
<i>Elagatis bipinnulatus</i> (Quoy and Gaimard).....	—	—			—	
<i>Elagatis bipinnulatus</i> (Quoy and Gaimard).....	—	—	—	—		
<b>CONGRIDAE—Conger eels</b>						
<i>Chiloconger</i> sp.....	—		—	W		
<b>CYBIIDAE—Wahoo</b>						
<i>Acanthocybium solandri</i> (Cuvier and Valenciennes).....	—	—	—	—		
<b>HAEMULIDAE—Grunts</b>						
<i>Anisotremus interruptus</i> (Gill).....	M	W	—	—		
<i>Anisotremus interruptus</i> (Gill).....	—				—	
<b>HOLOCENTRIDAE—Squirrelfish</b>						
<i>Holocentrus suborbitalis</i> (Gill).....	—				—	
<i>Myripristis occidentalis</i> Gill.....	—				—	
<i>Myripristis occidentalis</i> Gill.....	—	M	—		—	
<i>Myripristis occidentalis</i> Gill.....	—				—	
<i>Myripristis occidentalis</i> Gill.....	—				—	
<i>Myripristis occidentalis</i> Gill.....	—				—	
<i>Myripristis occidentalis</i> Gill.....	—				M	
<i>Myripristis occidentalis</i> Gill.....	—				—	

FISH TESTED	EXTRACT TESTED*					Intestinal Content
	Muscle	Liver	Gonads	Intestine	Viscera	
ISTIOPHORIDAE—Sailfish						
<i>Istiophorus greyi</i> Jordan and Hill.....	—	—	W	—		
KATSUWONIDAE—Skipjacks						
<i>Euthynnus lineatus</i> Kishinouye.....	—	—	W	—		
KYPHOSIDAE—Rudderfish						
<i>Kypbosus</i> sp.....	—				—	
LUTJANIDAE—Snappers						
<i>Aphareus furcatus</i> (Lacépède).....	—				—	
<i>Aphareus furcatus</i> (Lacépède).....	—				—	
<i>Aphareus furcatus</i> (Lacépède).....	—				M	
<i>Aphareus furcatus</i> (Lacépède).....	—	W	—	—		
<i>Aphareus furcatus</i> (Lacépède).....	—	—	—	M		
<i>Aphareus furcatus</i> (Lacépède).....	—	—	—	—		
<i>Lutjanus aratus</i> (Günther).....	W	M	—	—		
<i>Lutjanus jordani</i> (Gilbert).....	—		—		—	
<i>Lutjanus jordani</i> (Gilbert).....	—	—	—			
<i>Lutjanus jordani</i> (Gilbert).....	—	—	—			
<i>Lutjanus jordani</i> (Gilbert).....	—		—			
<i>Lutjanus viridis</i> (Valenciennes).....	M				W	
<i>Lutjanus viridis</i> (Valenciennes).....	—				—	
<i>Lutjanus viridis</i> (Valenciennes).....	—				—	
<i>Lutjanus viridis</i> (Valenciennes).....	—		—		—	
MULLIDAE—Surmulletts						
<i>Pseudupeneus xanthogrammus</i> Gilbert.....	—	—		—		
<i>Pseudupeneus xanthogrammus</i> Gilbert.....	—				—	
<i>Pseudupeneus xanthogrammus</i> Gilbert.....	—		—	—		
POMACENTRIDAE—Damselfish						
<i>Microspathodon bairdi</i> (Gill).....	—					
PRIACANTHIDAE—Big Eyes						
<i>Priacanthus cruentatus</i> (Lacépède).....	—				—	
<i>Priacanthus cruentatus</i> (Lacépède).....	—				—	
<i>Priacanthus cruentatus</i> (Lacépède).....	—				M	
SCARIDAE—Parrotfish						
Scarid sp. nov.....	—	M		—		
SERRANIDAE—Seabass						
<i>Dermatolepis punctatus</i> Gill.....	—	—	—	—		
<i>Dermatolepis punctatus</i> Gill.....	—	—	—	—		
<i>Dermatolepis punctatus</i> Gill.....	—		—	M		
<i>Epinephelus labriformis</i> (Jenyns).....	—		—	—		
<i>Epinephelus labriformis</i> (Jenyns).....	—		—	—		
<i>Mycteroperca olfax</i> (Jenyns).....	—		—	—		
<i>Mycteroperca olfax</i> (Jenyns).....	—	—	—	—		
<i>Paranthias colonus</i> (Valenciennes).....	—				—	
<i>Paranthias colonus</i> (Valenciennes).....	—				—	
<i>Paranthias colonus</i> (Valenciennes).....	—				—	
SPARIDAE—Porgies, pargo						
<i>Calamus taurinus</i> (Jenyns).....	—	W			M	
TETRAODONTIDAE—Puffers, Globefish						
<i>Arothron setosus</i> (Smith).....	S				S	
<i>Arothron setosus</i> (Smith).....	S	M		S		
<i>Arothron setosus</i> (Smith).....	S				S	



TABLE 1 (Continued)

FISH TESTED	EXTRACT TESTED*					
	Muscle	Liver	Gonads	Intestine	Viscera	Intestinal Content
TETRAODONTIDAE—Puffers						
<i>Arothron setosus</i> (Smith).....	S				S	
<i>Arothron setosus</i> (Smith).....	S				S	
<i>Arothron setosus</i> (Smith).....	S	S	S	S		
<i>Arothron setosus</i> (Smith).....	S				S	
<i>Arothron setosus</i> (Smith).....	S				S	
<i>Arothron setosus</i> (Smith).....	S	S	S	S		
<i>Arothron setosus</i> (Smith).....	—	S	—	—		M
<i>Arothron setosus</i> (Smith).....	S				S	
THUNNIDAE—Tunas						
<i>Neothunnus macropterus</i> Temminck and Schlegel...	—	—	—	—		
<i>Neothunnus macropterus</i> Temminck and Schlegel...	—	M	—	—		
TRIAKIDAE—White-tipped sharks						
<i>Triacnodon obesus</i> (Rüppell).....	—	—		—		
<i>Triacnodon obesus</i> (Rüppell).....	—	—	—	—		

\* Explanation of symbols used:  
—, results negative; W, weakly toxic; M, moderately toxic; S, strongly toxic.

SUMMARY

Twenty-one families of Cocos Island fishes, representing 33 species and a total of 96 specimens were tested in this study. Of these, 22 species and 41 specimens, or about 67 per cent of the species and 43 per cent of the specimens, were found to be toxic. The musculature and viscera were tested on 95 cases. Seventeen specimens or 41 per cent of the toxic fishes had poisonous musculature, whereas 39 or about 95 per cent had toxic viscera. Both musculature and viscera were poisonous in 15, or 37 per cent, of the toxic specimens.

The fishes most likely to be used as food which were found to have toxic musculature included only five species:

- Caranx caballus*
- Caranx melampygus*
- Anisotremus interruptus*
- Lutjanus aratus*
- Lutjanus viridis*

It should be noted that two of the genera, *Caranx* and *Lutjanus*, are well established causative agents of ichthyosarcotoxism that have been incriminated in both the Caribbean

Sea and throughout the tropical Pacific Ocean.

In general, the viscera are the portions of the fish which are most likely to be poisonous. A more complete analysis of the distribution of ichthyosarcotoxin in the body of the fishes examined is presented in Table 2. The fishes reported upon in this paper represent the major shore and some of the pelagic fish species likely to be used as food in the regions discussed. It was found that 76 per cent of the Cocos Island families contained toxic species.

The limited number of specimens collected for most of the species precludes the presentation of statistically valid results at this time. Much more study is necessary before definite conclusions can be reached regarding the edibility of species listed as "weakly positive" because of the difficulty of interpreting this reaction in terms of human symptomatology.

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TABLE 2  
SUMMARY OF RESULTS OF TESTS FOR TOXICITY OF FISHES TAKEN AT COCOS ISLAND

	SPECIES	SPECIMENS	MUSCLE	LIVER	GONADS	INTESTINES	VISCERA	INTESTINAL CONTENT
Total Tested	33	96	96	46	42	48	41	1
Total Found Toxic	22	41	17	14	5	13	15	1
Percentage Found Toxic	67	43	18	30	12	27	37	100

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# PACIFIC SCIENCE

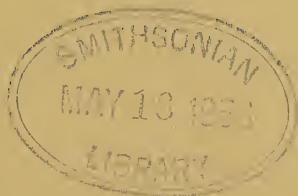
A QUARTERLY DEVOTED TO THE BIOLOGICAL  
AND PHYSICAL SCIENCES OF THE PACIFIC REGION



IN THIS ISSUE: Mawatari — *Bryozoa from the Kurile*

*Islands* • Chock — *Revision of Hawaiian Sophora* •

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## Cheilostomatous Bryozoa from the Kurile Islands and the Neighbouring Districts<sup>1</sup>

SHIZUO MAWATARI<sup>2</sup>

ABOUT A DOZEN YEARS have elapsed since Dr. Katsuzo Kuronuma very kindly placed his collection of Bryozoa from Kurile Islands at my disposal. Though I presented a preliminary report at the seventeenth annual meeting of the Zoological Society of Japan, the large part of my study on northern forms has been put away unpublished.

There have been only two papers published on the bryozoan fauna of the high north-western Pacific, both by Dr. Y. Okada. In 1918 he described 10 species from Dr. H. Marukawa's collection from Kamtschatka, and later (1933) he published a brief account of 14 species collected by the Northern Kurile Expedition of the Biogeographical Society of Japan. Our knowledge of the bryozoan fauna of these districts remains, therefore, very incomplete at present. To prepare this brief report, then, I have made a thorough re-examination of the northern material both in Okada's possession and my own.

### *Specimens*

1. From Kamtschatka, collected at spots near the estuary of the River Kishika by Dr. H. Marukawa, June 1912. Nos. 560-580.

<sup>1</sup> Contributions from the Research Institute for Natural Resources. No. 729. Studies on the Bryozoan Fauna of Japan and Adjacent Waters. No. 2. Manuscript received March 31, 1955.

<sup>2</sup> The Research Institute for Natural Resources, Shinjuku, Tokyo, Japan.

2. Taken by the Northern Kurile Expedition of the Biogeographical Society of Japan, collected by Mr. K. Koba in 1931.  
Off Ichinowatashi, Alaid Island. Nos. 1400-1412.  
Kitaura, Alaid Island Nos. 1413-1415.  
Off Arakawa, Paramushir Island. Nos. 1416-1420.  
Torishima, Paramushir Island. Nos. 1421-1438.
3. From Paramushir Island, collected by Dr. K. Kuronuma at a spot 10 miles south of the Island, August 1942. Nos. 4000-4021.
4. A part of the following material from Hokkaido.  
Akkeshi, coll. by Iwasa, July 1938. Nos. 1200-1221.  
Samani, coll. by Kuronuma, March 1944. Nos. 4200-4218.  
Akkeshi, coll. by Tanaka, August 1944. Nos. 4219-4251.  
Akkeshi, coll. by Okada, July 1945. Nos. 4508-4519.  
Kushiro, coll. by Nagamine, July 1950. Nos. 6201-6367.

Study of these collections has shown 45 species (including 2 undetermined forms) belonging to 15 families and 32 genera to be present. Six of the species are described as new. The known distribution of the species included is given in Table 1. In spite of the



TABLE 1  
KNOWN DISTRIBUTION OF THE SPECIES OF CHEILOSTOMATOUS BRYOZOA FOUND IN THE NORTHWESTERN  
PACIFIC

	ATLANTIC				PACIFIC				
	Arctic Ocean	Scandinavia	Europe (Mediterranean)	N. America	Alaska	Canada	U.S.A.	Japan (excl. Hokkaido)	China, Philippines, Malay
<i>Aetea anguina</i> .....	+	+	+	+		+	+	+	+
<i>Membranipora serrilamella</i> .....				+		+	+	+	
<i>Membranipora serrulata</i> .....	+	+		+					
<i>Conopeum reticulum</i> .....		+	+		+	+	+	+	+
<i>Electra crustulenta</i> var. <i>arctica</i> .....		+							
<i>Seculiflustra seculifrons</i> .....	+	+	+	+					
<i>Terminoflustra membranaceo-truncata</i> .....		+			+	+			
<i>Hincksina onychocelloides</i> sp. nov.....									
<i>Antropora japonica</i> .....								+	
<i>Cauloramphus spiniferum</i> .....		+			+	+	+	+	
<i>Callopora lineata</i> .....	+	+	+	+	+	+	+	+	
<i>Tegella armifera</i> .....	+	+		+	+	+	+	+	
<i>Tegella unicornis</i> .....	+	+	+	+	+	+	+		
<i>Microporina articulata</i> .....					+	+	+		
<i>Tricellaria ternata</i> .....	+	+	+				+	+	
<i>Tricellaria erecta</i> .....					+	+			
<i>Tricellaria unyoi</i> .....									
<i>Scrupocellaria scabra</i> .....	+	+	+	+	+			+	+
<i>Watersia kishikaensis</i> .....									
<i>Bugula californica</i> .....						+	+	+	
<i>Bugula</i> sp.....									
<i>Caulibugula aspinosa</i> sp. nov.....									
<i>Dendrobeania kurilensis</i> .....									
<i>Hippothoa hyalina</i> .....	+	+	+	+		+	+	+	+
<i>Hippothoa expansa</i> .....	+	+	+		+	+	+		
<i>Hippothoa divaricata</i> .....	+	+	+		+	+	+	+	
<i>Petraliella</i> sp.....									
<i>Stomachetosella sinuosa</i> .....		+			+	+			
<i>Umbonula arctica</i> .....	+	+			+	+	+		
<i>Schizoporella bidenkapi</i> .....		+							
<i>Codonellina operculata</i> sp. nov.....									
<i>Porella mucronata</i> sp. nov.....									
<i>Porella immersa</i> sp. nov.....									
<i>Porella acutirostris</i> .....	+	+	+		+				
<i>Porella marukawai</i> .....									
<i>Porella concinna</i> .....	+	+	+		+	+	+	+	
<i>Porella kurilensis</i> sp. nov.....									
<i>Smittina bella</i> .....	+	+		+	+	+	+	+	
<i>Parasmittina trispinosa</i> var.....		+	+	+		+	+	+	+
<i>Mucronella peachii</i> .....	+	+		+	+	+		+	
<i>Schizoretepora tumescens</i> .....								+	
<i>Siniopelta costazii</i> .....		+	+	+		+	+	+	+
<i>Siniopelta incrassata</i> .....		+	+		+	+	+	+	
<i>Myriozoum subgracile</i> .....	+	+	+		+	+	+	+	
<i>Myriozoella planum</i> .....	+								

fact that the materials have been obtained from somewhat confined localities and consequently they cannot provide a sufficient basis for a full discussion of the bryozoan fauna of these districts, the table will give a general idea of the faunistic constitution of the high northwestern Pacific.

Excluding two uncertain forms and 12 restricted species, 27 of the remaining 31 are known to occur in the Arctic Ocean or in the northern part of the Atlantic, thus indicating the overwhelming influence of colder waters on the fauna of this district. It may be rather surprising that only three of the species belong to the circum-pacific group.

I should like to express here my cordial thanks to Drs. Y. Okada and K. Kuronuma who have given me an opportunity to examine their interesting collections.

The figures have been drawn with the aid of a camera lucida at magnifications of 50 or 200 diameters.

## A N A S C A

### Family AETEIDAE

#### 1. *Aetea anguina* (Linnaeus), 1758

Fig. 1a

Zoarium adherent, occasional by branching. Zooecia elongate, creeping, granulated proximally; erect, tubular, curved, annulate distally. Membranous area subterminal, slightly expanded, punctured dorsally. An empty membranous ovisac was observed on the frontal membranous area near the distal end.

SPECIMENS EXAMINED: No. 4011 (Paramushir), No. 4221 (Akkeshi), Nos. 6238, 6317 (Kushiro).

### Family MEMBRANIPORIDAE

#### 2. *Membranipora serrilamella* Osburn, 1950

Fig. 1b

Zoarium encrusting especially on wider algae. Zooecia nearly elongate-quadrangular,

with thick walls and serrate cryptocyst, sometimes a longer spinule at the proximal end. A small hollow protuberance at each corner. Several specimens were obtained from the floating fronds of kelp.

SPECIMENS EXAMINED: No. 4013 (Paramushir), No. 4227 (Akkeshi), Nos. 6211, 6325 (Kushiro).

#### 3. *Membranipora serrulata* (Busk), 1881

Colony erect, bilamellar, sometimes *Steganoporella*-like, rising from widespread unilamellar encrusting base. Zooecia variable in size, rectangular or elongate oval, with slight, granulate proximal cryptocyst, serrate marginally. Zooecial orifice rather large, subquadrangular. No spines, no avicularia and no ovicells. Two distal and two lateral rosette-plates. A pair of distinct opercular glands.

SPECIMENS EXAMINED: No. 566 (Kamtschatka), No. 6318 (Kushiro).

#### 4. *Conopeum reticulum* (Linnaeus), 1767

Fig. 1e

Zoarium encrusting especially on broader algae, greyish white, thin, often gauze-like. Zooecia, variable, elongate quadrangular or hexagonal, separated by grooves or lines. Walls thickly calcified, high, smooth or denticulate. Cryptocyst narrow, descending, granulate, surrounding oval, elliptic or circular opesia. A pair of triangular knob-like spaces, depressed or closed, on the proximal corners of short gymnocyst. Irregular rounded spaces sometimes scattered. Ooecia and avicularia wanting.

SPECIMENS EXAMINED: No. 1405 (Alaid), No. 4019 (Paramushir), No. 4233 (Akkeshi), No. 6235 (Kushiro).

### Family ELECTRINIDAE

#### 5. *Electra crustulenta* var. *arctica* (Borg), 1931

Fig. 1d



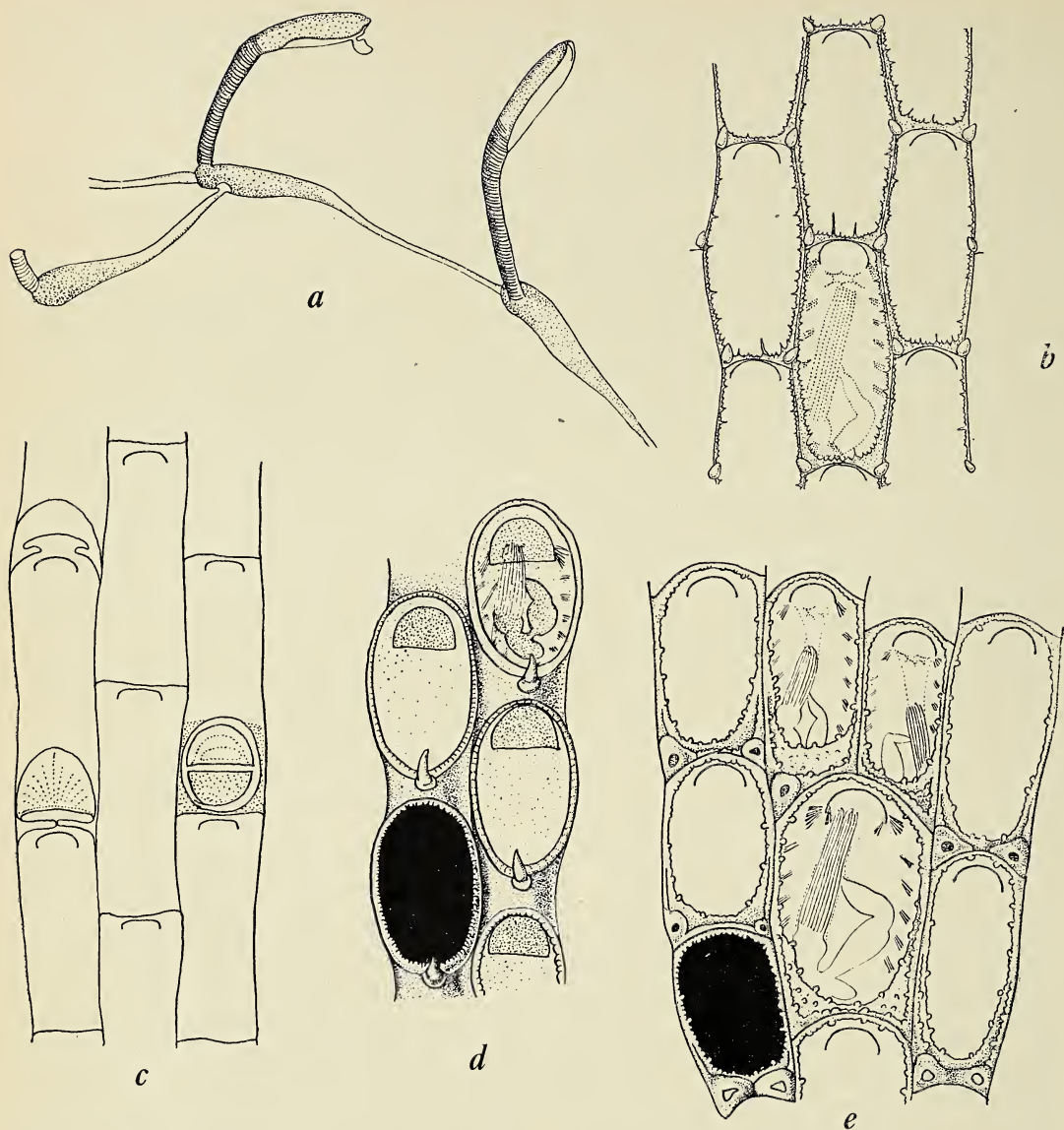


FIG. 1. *a*, *Aetia anguina* (Linnaeus); part of a creeping colony. *b*, *Membranipora serrilamella* Osburn; frontal view of zooecia with covering membrane. *c*, *Seculiflustra seculifrons* (Pallas); frontal view of zooecia, an interzooecial avicularium and two developing ooecia. *d*, *Electra crustulenta* var. *arctica* (Borg); zooecia with large calcified operculum. *e*, *Conopeum reticulum* (Linnaeus); frontal view of zooecia.

Zoarium encrusting, thin. Zooecia elliptical, separated by furrows, with thickened, granulate mural rim and vestigial cryptocyst. Gymnocyte smooth, developed, with a single strong spinous process rising just proximal to the opesia. Operculum calcified, white.

Several specimens were obtained on shells and stones, they are easily distinguished by the calcified operculum and proximal process.

SPECIMENS EXAMINED: No. 1434 (Paramushir), Nos. 6215, 6217, 6336, 6341 (Kushiro).

## Family FLUSTRIDAE

6. *Seculiflustra seculifrons* (Pallas), 1766

Fig. 1c

Zoarium erect, frondose, rather narrow, truncate terminally. Zooecia elongate-quadrangular or elongate-hexagonal, simple, without spines. Avicularia vicarious, rectangular basally, subcircular or oval in frontal view. Mandibles semi-elliptical, deep yellow.

Ooecia immersed, oval, with radially striated frontal, closed with overarching lateral ribs.

SPECIMENS EXAMINED: No. 569 (Kamtschatka), No. 6281 (Kushiro).

7. *Terminoflustra membranaceo-truncata* (Smitt), 1867

Zoarium erect, unilaminar, thin, irregularly flabellate. Zooecia elongate hexagonal, truncate, with a minute spine at each distal corner. Avicularia square, mandibles semicircular. Ooecia endozooecial, small.

SPECIMENS EXAMINED: No. 1416 (Paramushir), No. 6201 (Kushiro).

## Family HINCKSINIDAE

8. *Hincksina onychocelloides* sp. nov.

Fig. 2a-c

Zoarium encrusting, thin, coarse, irregular, dark brown. Zooecia oval or hexagonal, arranged alternately in radiating rows. Frontal membrane occupies the whole front bordered with thin, granulate, inclined walls and narrow marginal cryptocyst. Operculum (Fig. 2c) rather thickened marginally, low, transverse. Vicarious avicularia occurring in longitudinal rows, elongate-elliptic, without bar and conspicuous teeth. Mandible (Fig. 2b) elongate-triangular, with proximally bifurcate long median sclerite extending terminally beyond the membranous wing, similar to that of *Onychocella*. A single distal and two lateral rosette plates. Minute spinous processes on the dorsal wall, probably for attachment.

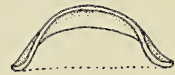
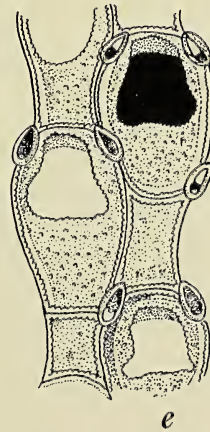
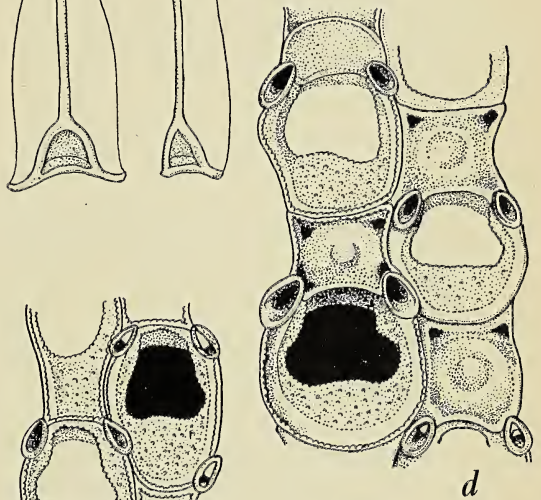
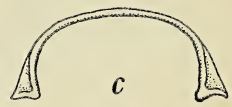
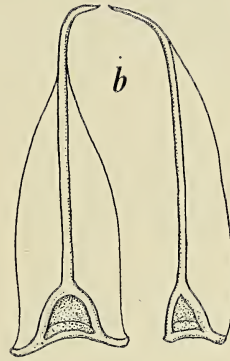
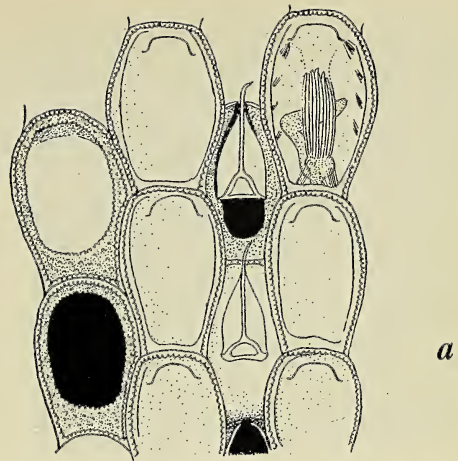


FIG. 2. a-c, *Hincksina onychocelloides* n. sp.: a, Frontal view of zooecia and two vicarious avicularia; b, avicularian mandibles with wings and produced median carina; c, operculum. d-g, *Antropora japonica* (Canu and Bassler): d, Frontal view of fertile zooecia with ooecia covering the interopesia spaces; e, young zooecia; f, operculum; g, delicate mandibles of dependent avicularia.



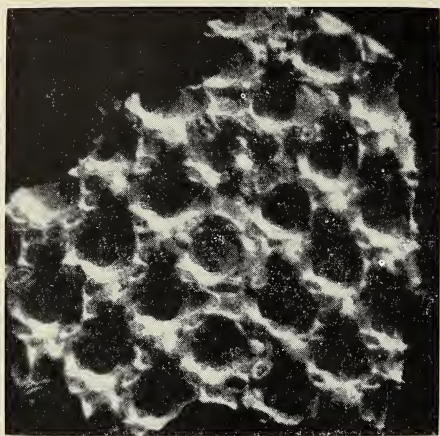


FIG. 3. *Antropora japonica* (Canu and Bassler), photomicrograph of calcined specimen.

This species is peculiar in having very wide opesia and *Onychocella*-type avicularian mandibles. It is somewhat doubtfully placed under *Hincksina*.

SPECIMENS EXAMINED: No. 4209 (Paramushir), Nos. 1206, 4223, 4513 (Akkeshi).

9. *Antropora japonica* (Canu and Bassler), 1929

Figs. 2*d*-*g*, 3

*Membrendoecium japonicum* Canu and Bassler (1929).

Zoarium encrusting, flat, irregularly lobate. Zooecia oval, hexagonal or quadrangular, very large, completely covered by brownish membrane. Frontal surrounded by thick, raised, granulate walls. Cryptocyst developed proximally, extending along the lateral walls, minutely granulate. Opesia nearly trifoliate, large, characteristic. Avicularium on a thickened protuberance at each distal corner, with pointed rostrum and delicate triangular mandible (Fig. 2*g*). Peculiar quadrangular interopesia area covered by membrane with or without separating walls. Fertile zooecia (Fig. 2*d*) larger and broader, with developed cryptocyst. Ooecium distinct, globose, umbonate,

situated commonly on the quadrangular interopesia space. A single terminal pore-chamber with four multiporous rosette plates, and two pairs of lateral pore-chambers with multiporous rosette plates. Opercular valve (Fig. 2*f*) low and broad.

The type locality is near Cape Tsugaru (misprinted as Tsiuka). The species is to be classified in *Antropora* not in *Membrendoecium*.

SPECIMENS EXAMINED: Nos. 4005, 4006 (Paramushir).

10. *Cauloramphus spiniferum* (Johnston), 1838

Fig. 4*a*

Zoarium encrusting stones or shells. Zooecia moderately large, with raised gymnocyst. Opesia oval or elliptic. Cryptocyst slight, sometimes vestigial. Opesia spines moderate; 10 to 13 in number, overarching the opesia. A small pedicellate avicularium with minute mandible among spines on each side, but slightly outside of the row of spines. Ooecium probably wanting.

SPECIMENS EXAMINED: No. 4021 (Paramushir), No. 4201 (Samani), Nos. 6209, 6256 (Kushiro).

11. *Callopora lineata* (Linnaeus), 1768

Fig. 4*b*

Zoarium encrusting, unilaminar, irregular, brownish. Zooecia distinct, oval, with raised walls. Frontal membranous area reduced, gymnocyst developed proximally. Opesia oval, a little broadened proximally, with thickened margin. Opesia spines, three or six on each side, obliquely overarched. Cryptocyst very narrow, linear and granulate. A triangular, suboral avicularium usually on a prominent globular umbo. Ooecia large, globose, flattened frontally, always traversed by thickened rib, and usually surmounted by an avicularium.

SPECIMENS EXAMINED: No. 571 (Kamtschatka), No. 4001 (Paramushir), No. 4208 (Samani), No. 4229 (Akkeshi).

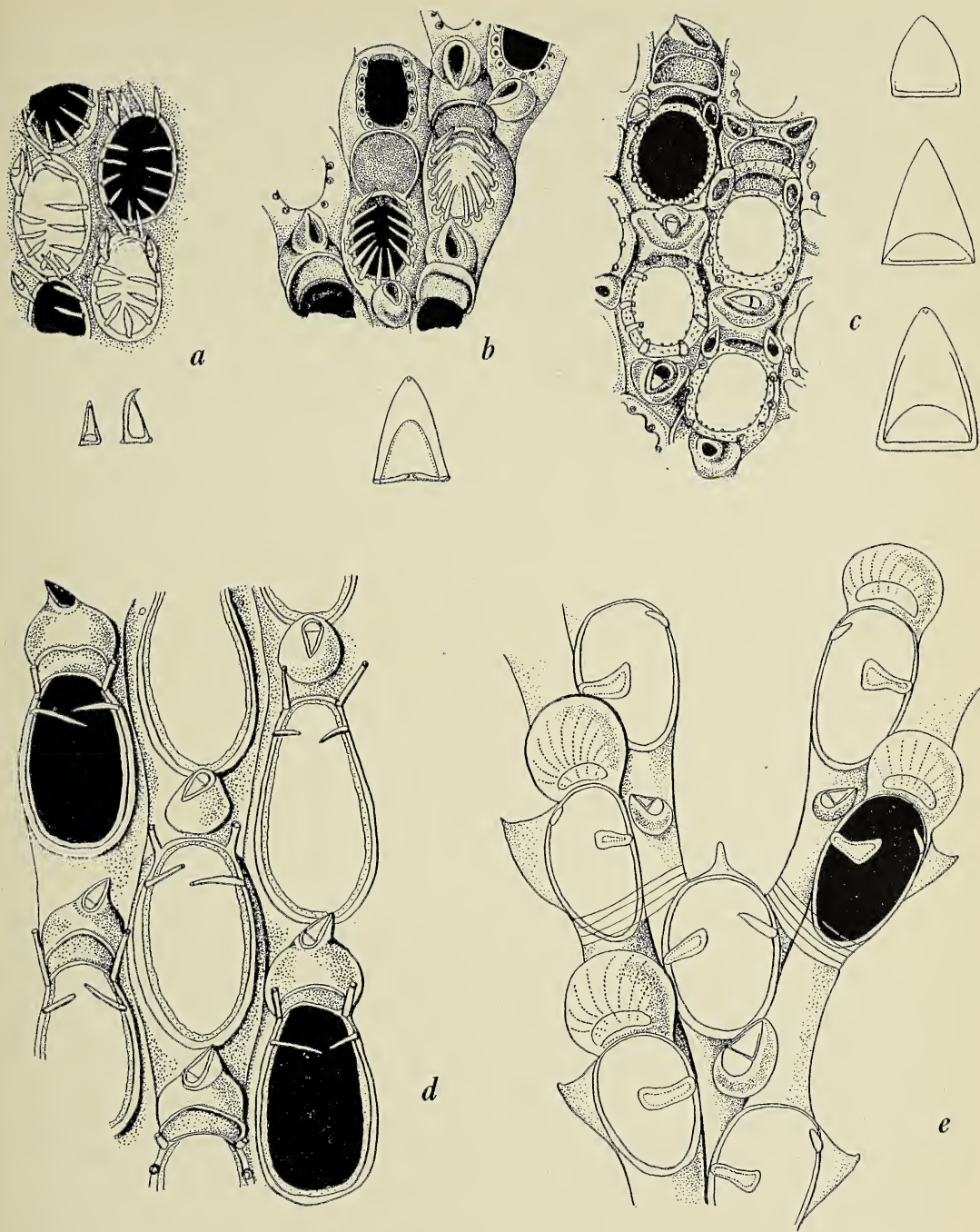


FIG. 4. *a*, *Cauloramphus spiniferum* (Johnston), frontal view of zooecia with spiniferous avicularia and minute mandibles of avicularia. *b*, *Callopora lineata* (Linnaeus), fertile zooecia with ooecia superposed by frontal avicularia and detail of mandible of frontal avicularium. *c*, *Tegella armifera* (Hincks), frontal view of fertile zooecia and details of mandibles of frontal avicularia. *d*, *Tegella unicornis* (Fleming), matured zooecia and frontal avicularia. *e*, *Tricellaria erecta* (Robertson), frontal view of diverging branches.



12. *Tegella armifera* (Hincks), 1880

Fig. 4c

Zoarium encrusting, pale brown or grey. Zooecia large, distinct, separated by furrows. Gymnocyst about one-third or one-half of the frontal, convex, with large suboral avicularium on a prominent umbo. Opesia large, broad, with granular marginal cryptocyst and raised borders. Two or four opesial spines on each side, and a raised lateral avicularium on each distal corner. Ooecia globose, with flattened frontal surface limited by a transverse bar. Suboral avicularium close to the preceding ooecium. Two distal and four lateral multiporous rosette plates.

The direction of lateral avicularia and the full number of opesial spines differ from Osburn's description (Osburn, 1950), thus suggesting a distinct variety.

SPECIMENS EXAMINED: No. 4020 (Paramushir), No. 6320 (Kushiro).

13. *Tegella unicornis* (Fleming), 1828

Fig. 4d

Zoarium encrusting, irregular, yellow or brown. Zooecia regularly arranged, moderate with raised walls. Gymnocyst less than one-third of the frontal length. Opesia oval, narrowed distally with thickened margin and narrow cryptocyst minutely serrate; four spines near the distal end of opesia. Ooecia large, elongate, globose, with distinct transverse rib. Suboral avicularium comparatively large, prominent on an umbo, triangular mandible extending obliquo-proximally. Marcus suggested that Okada's specimens might belong to *T. robertsonae* but my reexamination has proved the correctness of Okada's identification.

SPECIMENS EXAMINED: No. 561 (Kamtschatka), No. 1403 (Alaid), No. 4214 (Samani), No. 6033 (Kushiro).

## Family MICROPORIDAE

14. *Microporina articulata* (Fabricius), 1821

Zoarium erect, dichotomously branching, articulated, Cellariiform, attached by rootlets. Internodes stout; zooecia around the zoarial axis, very elongated quadrangular, separated by furrows. Frontal flat, thick, minutely perforate and occasionally granulate, encircled by salient ridges. Opesia semicircular or semi-elliptic, with straight proximal border. Opesiules small, rather indistinct, slit-like. Avicularia oval, prominent, limited by salient ridges, immersed at the proximal end of the zooecium. Ovicells endozooecial.

SPECIMENS EXAMINED: No. 1409 (Alaid), No. 1425 (Paramushir), No. 6231 (Kushiro).

## Family SCRUPOCELLARIIDAE

15. *Tricellaria ternata* (Solander), 1786

Zoarium erect, white, bushy, expanded or confervoid. Branches straggling, internodes consisted of three to five zooecia. Chitinous joint traversing the base of both inner and outer zooecia proximally to the opesia. Zooecia slender, much attenuated below, with elliptic opesia. Scutum variable from a mere spine to spatulate plate. One or two inner and two or three outer spines on the distal margin. A small frontal avicularium on the axial zooecium. Lateral avicularium large and prominent. Ooecia large, globose rather elongate and imperforate. Radical fibres from a circular disc outside the opesia. Long claspers from a small chamber above the lateral avicularium, enlarged terminally.

SPECIMENS EXAMINED: No. 1410 (Alaid), Nos. 1422, 1436 (Paramushir), No. 6321 (Kushiro).

16. *Tricellaria erecta* (Robertson), 1900

Fig. 4e

Zoarium erect, with very long branches rather like that of *Scrupocellaria*. Zooecia biserial, attenuate proximally, with crenulate, raised margins and one or two spines at the outer corner. Scutum rather narrow, spatulate, occasionally broad and bifid; frontal avicularia generally on each zooecium, lateral avicularia

variable, often vestigial. Ooecia globose, striated and fenestrated. Joint traversing the base of the outer opesia.

SPECIMENS EXAMINED: No. 1419 (Paramushir), No. 4213 (Samani).

17. *Tricellaria unjoi* (Okada), 1918

Zoarium bushy, 2–3 cm. in height, milky white (in spirits). Branches delicate, biserial, internodes of three to five or five to nine zooecia. Zooecia elongate, narrowed proximally, with elliptic opesia. Two short spines on the outer opesial margin; scutum varying from a spinous process to a spatula. Marginal avicularia large, frontal avicularia wanting. Rootfibres from small chambers above the avicularia. Ooecia oval, globular, smooth with faint striations and peculiar elliptic median fenestra.

SPECIMEN EXAMINED: No. 565 (Kamtschatka).

18. *Scrupocellaria scabra* (van Beneden), 1848

Zoarium erect, bushy, stout. Internodes long, three to ten or more zooecia in a series. Joint traversing just proximally to the outer opesia or slightly involving it. Zooecia elongate, with curved outer margin. Opesia about half of the frontal length, oval, with developed cryptocyst and raised margin. Scutum very large, oval or flared, with branched internal cavity. A small inner spine and one or two outer spines on the distal corners. Marginal avicularia large, conspicuous on all of the zooecia. The frontal avicularia small, rather rare. Vibracula small, rather inconspicuous, transverse, above the avicularian chamber with transverse groove. Flagellum shorter than zooecia, somewhat stout, often wanting.

Ooecia subglobose, with striate triangular area on the front.

SPECIMENS EXAMINED: No. 1429 (Paramushir), No. 1211 (Akkeshi).

Family *BIALLARIELLIDAE*

19. *Watersia kishikaensis* (Okada), 1918  
Fig. 5a

*Flustra episcopalis* var. *simplex* Okada (1917).  
*Flustra simplex* var. *kishikaensis* Okada (1918).  
*Euthyroides simplex* var. *kishikaensis* Okada (1921).

Zoarium erect, frondose, fan-shaped, bilaminar. Branches widened distally to the subtruncate end. Zooecia elongate-quadrangular, narrow; marginal kenozoecia much elongated. Orifice subterminal, broad, closed by opercular valve. Avicularia vicarious, elongate oval with radiating frontal striations and quadrangular base; mandible semicircular, broad.

Ooecia large, prominent, distinctly carinate, with paired elliptic fenestra and faint radiating lines.

SPECIMENS EXAMINED: No. 579 (Kamtschatka), No. 6290 (Kushiro).

20. *Bugula californica* Robertson, 1905

Zoarium erect, thick, bushy. Opesia about two-thirds of the frontal, with two to four short, stout spines on the distal corners. Avicularia large, robust, a little distal to the middle of the outer wall. Ancestrula with a median suboral spine and three or five distal spines. Ooecia unknown.

SPECIMEN EXAMINED: No. 4016 (Paramushir).

21. *Bugula* sp. undet.

Zoarium erect, bushy, delicate and small. Zooecia slender, with short proximal gymnocyst and truncate distal end. Opesia occupies the larger part of the frontal, with two outer and one inner spines on the corner. Avicularia small, rounded or elliptic, near the proximal end of the opesia on the outer wall. Ooecia globose, attached to the middle line. Rootlets numerous.

As the specimens are all fragmentary, the determination is postponed until more complete material is obtained.

SPECIMENS EXAMINED: No. 1207 (Akkeshi), No. 1428 (Paramushir).



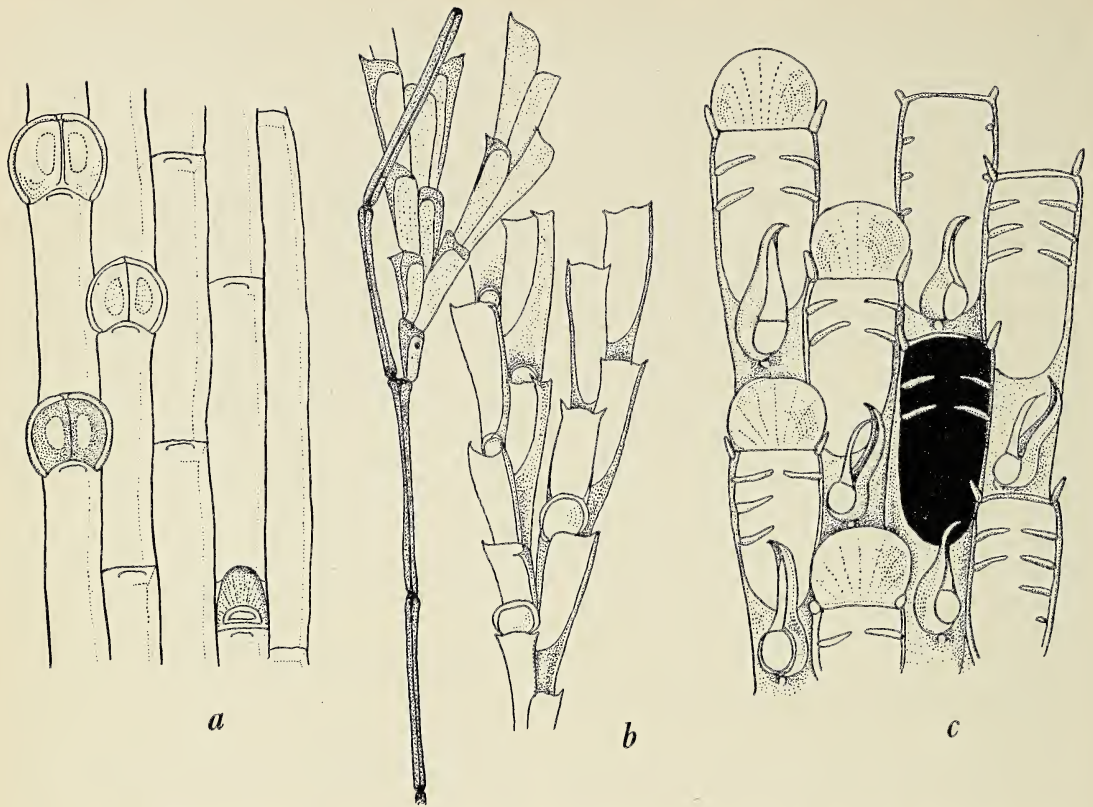


FIG. 5. *a*, *Watersia kishikaensis* (Okada), frontal view of marginal part of a lobate branch; elongated marginal kenozoecium, vicarious avicularium and fertile zooecia with carinate globose ooecia. *b*, *Caulibugula aspinosa* n. sp., keeled stem-kenozoecia, origin of functional branches and fertile internodes with ovicelled zooecia are indicated. *c*, *Dendrobeatia kurilensis* (Okada), fertile part of an internode; striated ooecia and long beaked frontal avicularia are figured.

## 22. *Caulibugula aspinosa* sp. nov.

Fig. 5*b*

Zoarium erect, biserial, delicate, bushy on a slender stem. Proximal kenozoecia of the stem elongate, tubular, strengthened by longitudinal ribs. Autozooecia elongate-quadrangular, attenuate below, truncate or a little oblique distally. Opesia large, occupying the large part of the frontal, without long spines but with a short process at each distal corner, sometimes wanting. Avicularia moderate, elliptic, on the proximal gymnocyst but rather rare. Ooecia prominent, attached near the distal inner corner of the fertile zooecia.

The present species clearly belongs to

*Caulibugula*, but is rather peculiar inasmuch as it lacks long spines. The general form of the zooecial tuft is very close to that of *Bugula*.

SPECIMENS EXAMINED: No. 1402 (Alaid), No. 4512 (Reisui).

## 23. *Dendrobeatia kurilensis* (Okada), 1933

Fig. 5*c*

*Bugula japonica kurilensis* Okada (1933).

Zoarium frondose, multiserial, without connecting tubes. Zooecia with a distal process and one to four spines on each lateral wall. Median proximal avicularia moderate, with peculiarly long, curved beak. Ooecia mod-

erate. The long curved avicularian rostrum is peculiar.

SPECIMENS EXAMINED: No. 1407 (Alaid), Nos. 4228, 4519 (Monsei).

## ASCOPHORA

### Family HIPPOTHOIDAE

#### 24. *Hippothoa hyalina* (Linnaeus), 1767

Zoarium encrusting, thin, hyaline, glistening or multilamellar, irregularly piled up, rough, opaque. Zooecia more or less separated, pyriform, convex, transversely ribbed, encircled by a row of fenestrae. Orifice terminal, circular, with rounded shallow sinus and thin peristome. Female zooecia a little smaller, male zooecia minute, occurring irregularly, with marginal perforations and branching suture.

SPECIMENS EXAMINED: No. 564 (Kamtschatka), No. 1418 (Paramushir), No. 4014 (Paramushir), No. 4217 (Samani), No. 4238 (Akkeshi), No. 6203 (Kushiro).

#### 25. *Hippothoa expansa* Dawson, 1859

Figs. 6a-e, 7a, b

Zoarium thin, flat, flabellate or palmate, branched. Zooecia arranged in two or three rows, elliptic or pyriform, convex, with developed basal expansion and strong, transverse striations. Orifice subcircular, with broad shallow sinus closed by operculum (6e). Fertile zooecia shorter, with orifice straight proximally. Ooecium (6c) large, globose, broad, umbonate, thickened marginally. Operculum of fertile zooecium (6d) semi-circular, that of ordinary zooecia with proximal projection. Interesting connecting tubes (6b) are seen in optical section.

Occurrence of two types of opercula is the most striking feature to distinguish this species from *H. divaricata*.

SPECIMENS EXAMINED: No. 4007A (Paramushir), No. 6301 (Kushiro).

#### 26. *Hippothoa divaricata* Lamouroux, 1821

Figs. 6f-b, 7c

Zoarium creeping, uniserial, branched, ramose, delicate. Zooecia elongate-pyriform, convex, very slightly striated with narrow basal expansion and longitudinal carina. Orifice rounded, with broad sinus. Fertile zooecium smaller, with similar orifice and operculum (6g) to those (6b) of ordinary one. Ooecia globose (6g), smooth, slightly umbonate. Zoarial arrangement and zooecial form somewhat variable. Because of these variations the varietal names *conferta* and *carinata* have been proposed.

SPECIMENS EXAMINED: Nos. 1431, 4007B, 4018 (Paramushir), No. 4212 (Samani), No. 1218 (Akkeshi), No. 6290 (Kushiro).

### Family PETRALIIDAE

#### 27. *Petraliella* sp.

Fig. 8a-c

Zoarium encrusting, thick, greyish white. Zooecia moderate, oval or hexangular, arranged alternately. Frontal convex, rather reticulate or ribbed with infundibular pores. Orifice and operculum (8b) very large, semi-elliptic or subquadrangular with straight lateral and proximal margins. A large, elliptic avicularium with semi-elliptic mandible (8c) on a salient suboral mucro.

The species resembles in general appearance *Cryptosula pallasiana* and *Petraliella armata*, but differs in the large orifice and semicircular mandible. The specimen is not complete, being without ovicells. It is tentatively referred to *Petraliella*.

SPECIMEN EXAMINED: No. 1427 (Alaid).

### Family SCHIZOPORELLIDAE

#### 28. *Stomachetosella sinuosa* (Busk), 1860

Figs. 8d, e, 9

Zoarium encrusting, circular, thick, dark reddish brown or brownish purple. Zooecia hexagonal or elliptic, with rather sinuate mar-



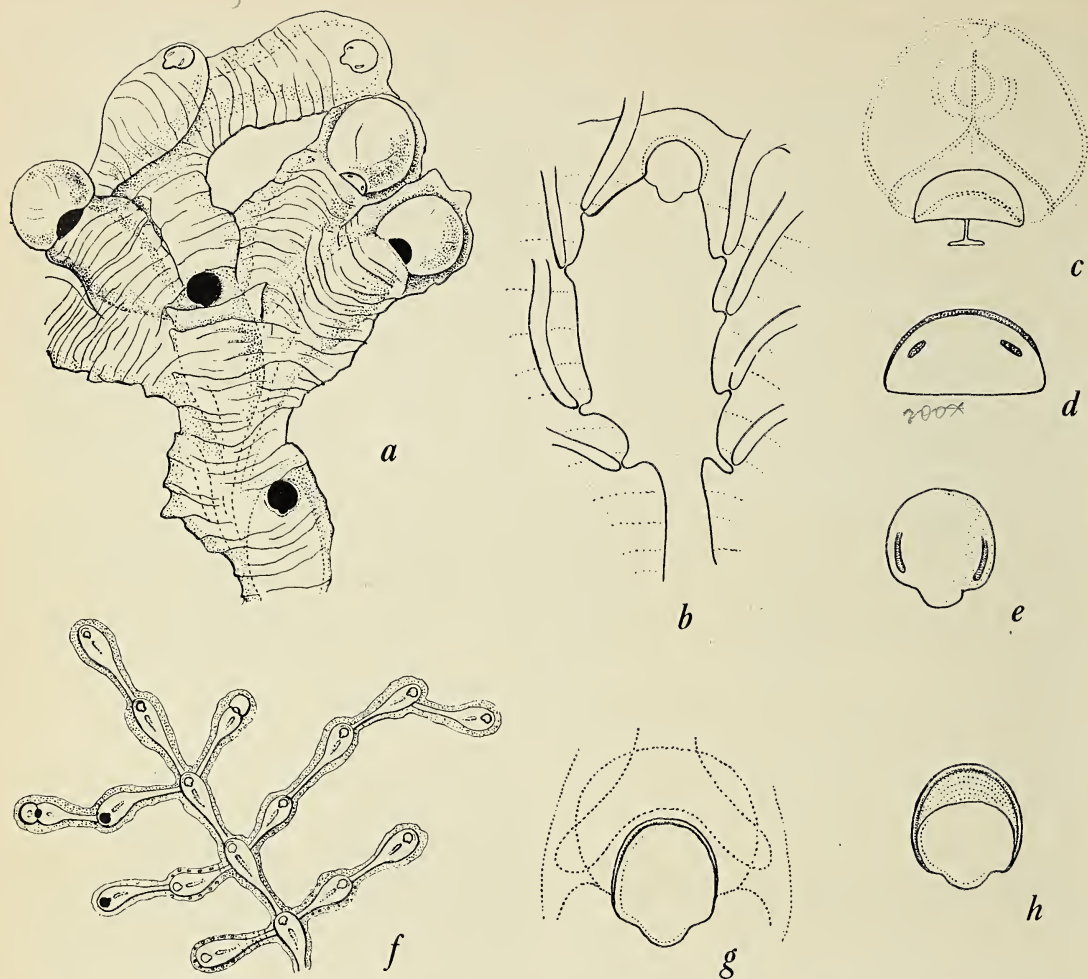


FIG. 6. *a-e*, *Hippothoa expansa* (Dawson): *a*, Part of an incrusting zoarium with semiglobular oecia; *b*, basal view of a zooecium, indicating the connecting tubes; *c*, structure of an oecium and aperture; *d*, operculum of a fertile zooecium; *e*, operculum of an immature zooecium. *f-h*, *Hippothoa divaricata* Lamouroux: *f*, Frontal view of a branching colony; *g*, structure of fertile zooecium with oecial cavity and the proximal end of the succeeding zooecium; *h*, operculum.

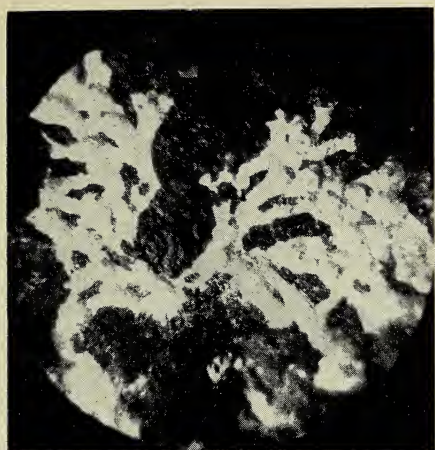
gin. Frontal thick, granular, convex or immersed, with large infundibular pores. Orifice circular or transversely elliptic with thin, pyriform peristome. No spines, no avicularium. Oecia large, deeply immersed, with circular median pore. Four lateral and two distal multiporous rosette plates, Operculum (8e) circular, with proximal projection and lateral muscular insertions.

This is the *Schizoporella sinuosa* of various authors.

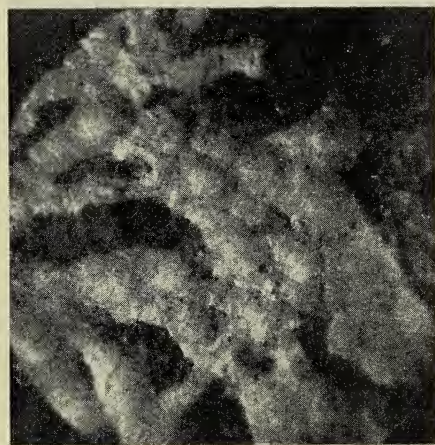
SPECIMENS EXAMINED: No. 1421 (Paramushir), No. 4226 (Akkeshi).

## 29. *Umbonula arctica* (M. Sars), 1851

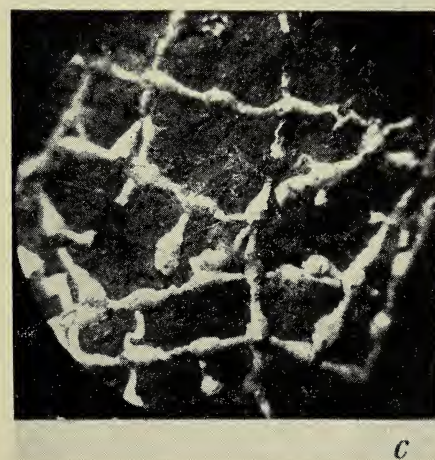
Zoarium encrusting or foliaceous, unilamellar or bilamellar. Zooecia large, oval, quinuncial, convex, elevated distally. Frontal ribbed, areolate. Orifice large, orbicular with low peristome and suboral small mucro. A small avicularium with rounded mandible on



a



b



c

FIG. 7. Photomicrographs of calcined specimens of: a, b, *Hippothoa expansa* Dawson; c, *H. divaricata* Lamouroux.

each side of the orifice. Ooecia large, globose, immersed.

SPECIMENS EXAMINED: No. 1400 (Alaid), No. 4012 (Paramushir), No. 4216 (Samani), No. 6305 (Kushiro).

30. *Schizoporella bidenkapi* Nordgaard, 1902

Figs. 8f, g, 9

Colony encrusting, circular, thick. Zooecia large, hexagonal or quadrangular, with salient separating threads. Frontal thickened tremocyst, granular. Immersed orifice transverse, elliptic, produced proximally. Peristome deep, with circular orifice. Operculum (8g) subquadrangular with arched distal margin and incomplete lateral sclerites. Two distal and four lateral rosette plates. Avicularia wanting or vestigial, immersed, with minute mandible (8g).

SPECIMEN EXAMINED: No. 4004 (Paramushir).

Family SMITTINIDAE

31. *Codonellina operculata* sp. nov.

Figs. 8b-k, 9

Zoarium encrusting, thin, irregular, white and shining or pale purplish brown. Zooecia elongate elliptic or hexagonal separated by salient threads, slightly convex, smooth, perforated by regular circular pores. Orifice subcircular, with large sinus limited by broad cardelles, surrounded by thin peristome. Median suboral avicularium large, subquadrate, spatulate. Ooecium globular, perforate and marginate, bordered by peristome proximally. Operculum (8i) with submarginal short sclerites. Mandible (8j) with bifurcate median sclerite. Two distal and four lateral multiporous rosette plates (8k).

The species is allied to *Codonellina spatulata* (Okada and Mawatari), but is distinctly separated by its operculum and mandible.

SPECIMENS EXAMINED: No. 4015 (Paramushir), No. 4205 (Samani), Nos. 4219, 4517 (Akkeshi).



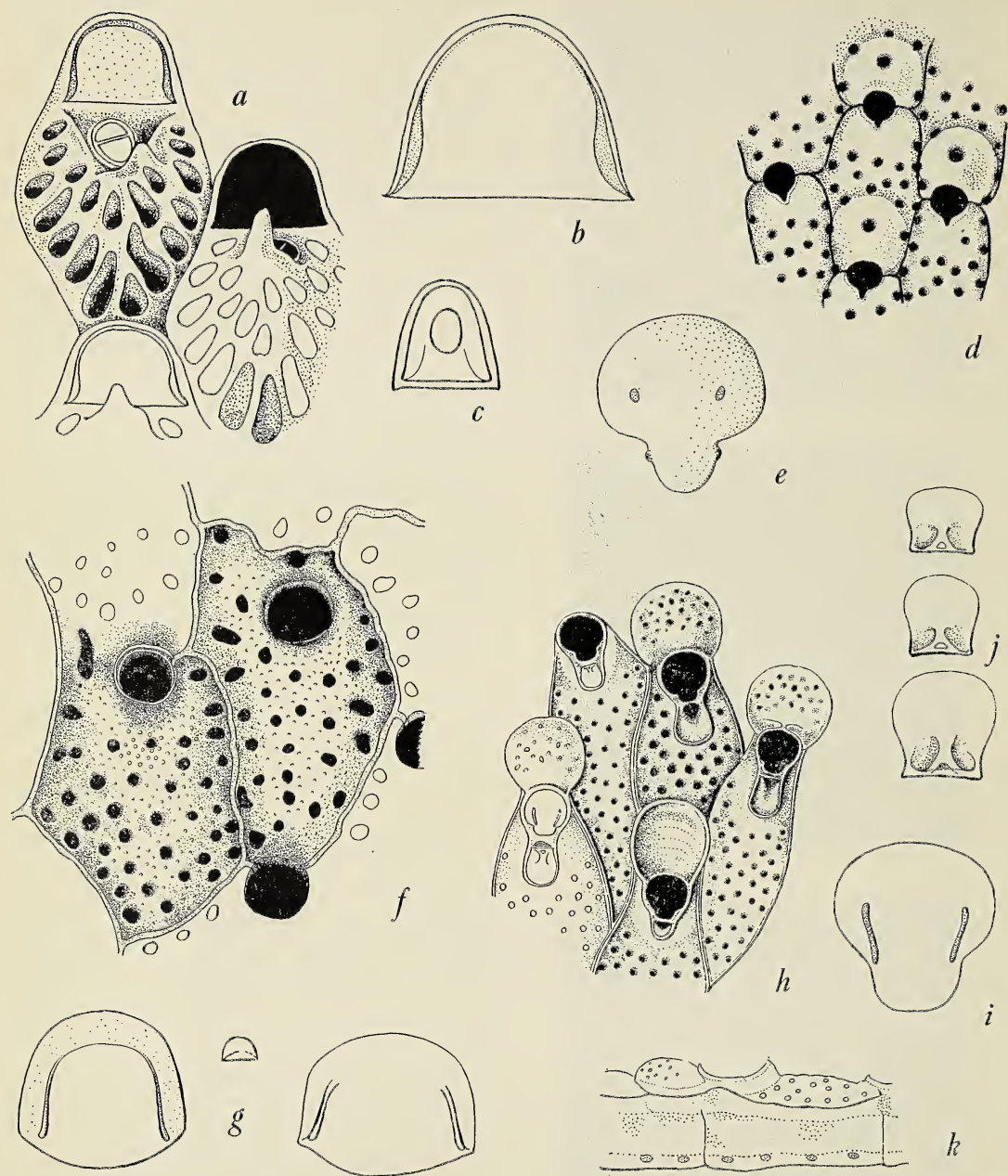


FIG. 8. *a-c*, *Petraliella* sp.: *a*, Frontal view of zooecia with subopercular process and an avicularium; *b*, operculum; *c*, mandible of the frontal avicularium. *d, e*, *Stomachetosella sinuosa* (Busk): *d*, Zooecia with perforated oecia; *e*, operculum. *f, g*, *Schizoporella bidenkapi* Nordgaard: *f*, Frontal view of zooecia; *g*, two opercula and a minute mandible of rare frontal avicularium. *h-k*, *Codonellina operculata* n. sp.: *h*, Frontal view of fertile zooecia with porous ovicells; *i*, operculum; *j*, frontal mandibles; *k*, lateral view of a zooecium.



32. *Porella mucronata* sp. nov.

Figs. 10a-d, 11a

Zoarium erect, branched, flattened or thickened, bilaminar or multilaminar. Zooecia large, oval or hexagonal, globose, becoming immersed with age. Frontal thick pleurocyst, with small number of deep areolar pores and submedian, suboral mucro supporting a circular avicularium. Orifice very large, semi-circular or subquadrangular, deeply immersed in the thickened peristome. Peristomial orifice with sinus. Ooecium globose, deeply immersed, opening into the peristome but not closed by operculum. Two lateral and one distal multiporous rosette plates. Operculum (10b) with strong lateral sclerites; mandible (10c) with marginal denticles. Large avicularian cavity is figured in section (10d).

The frontal pleurocyst, non-perforate ooecia, and suboral, submedian avicularia appear to me to indicate the position of the species near *Porella*.

SPECIMENS EXAMINED: No. 1413 (Alaid), No. 4210 (Samani).

33. *Porella immersa* sp. nov.

Figs. 10e-g, 11b

Zoarium disciform, dark brown or purple. Zooecia elliptic, subhexagonal, separated by furrows. Frontal convex pleurocyst, minutely granular with 8 to 13 small areolar pores. Orifice subcircular, with broad shallow sinus, concealed within a deep peristome. A small circular suboral avicularium on the raised frontal wall. Ooecia deeply immersed and concealed rather completely. Operculum (10e, f) subcircular with thickened margins and muscular insertions. Mandibles (10g) semi-circular with bifurcate median sclerite.

SPECIMENS EXAMINED: No. 4017 (Paramushir), No. 1209 (Akkeshi), No. 4207 (Samani).

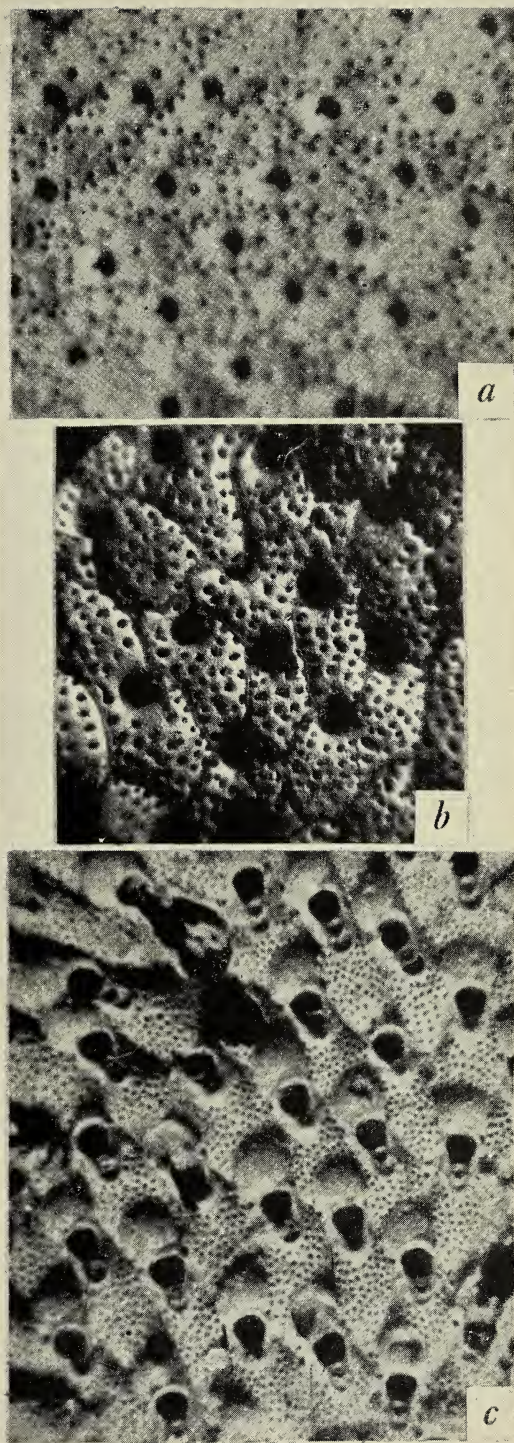


FIG. 9. Photomicrographs of calcined specimens of: a, *Stomachetosella sinuosa* (Busk); b, *Schizoporella bidenkapi* Nordgaard; c, *Codonellina operculata* n. sp.



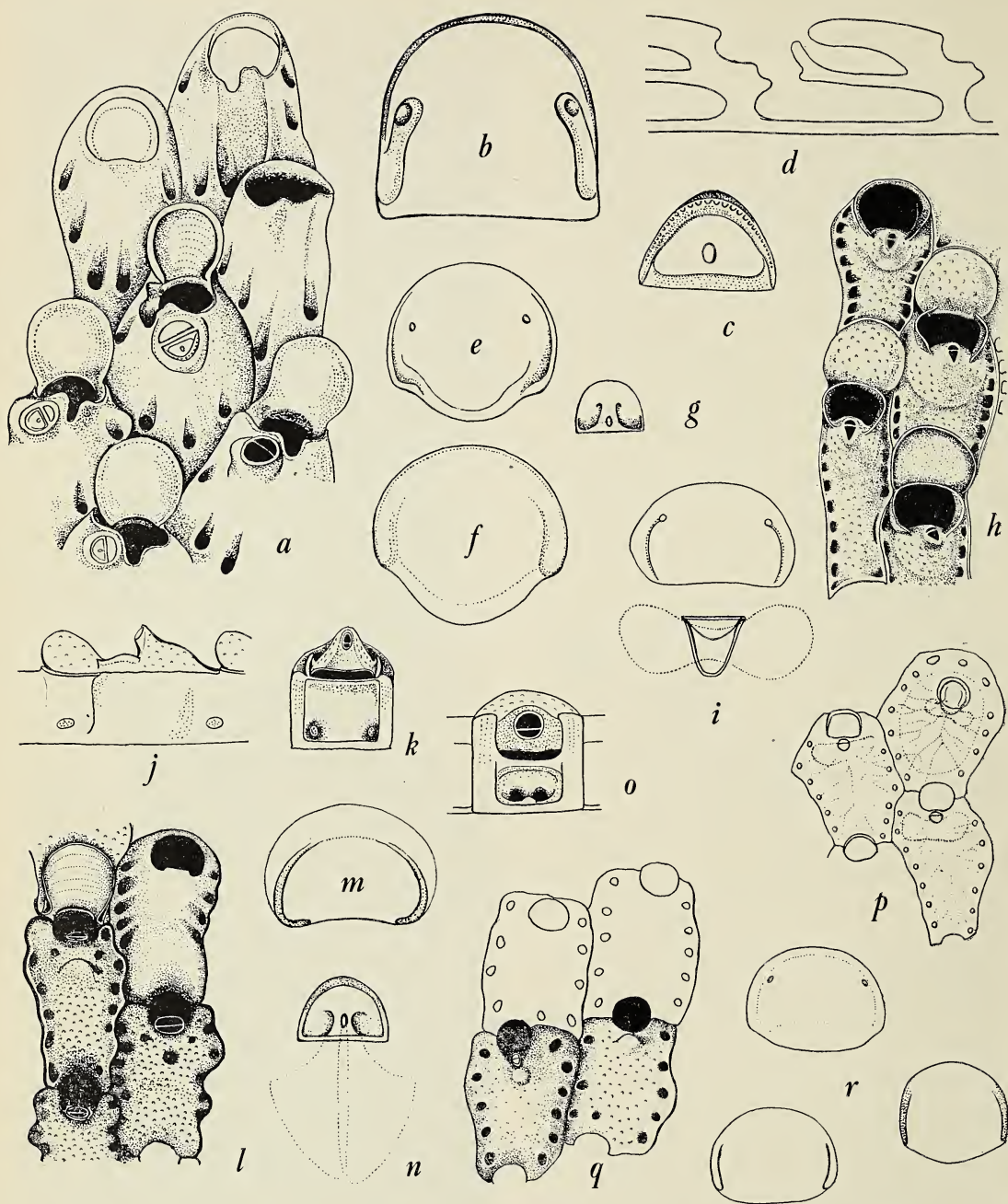


FIG. 10. *a-d*, *Porella mucronata* n. sp.: *a*, Frontal view of a part of the colony near the growing margin indicating the development of ooecia and peristomes; *b*, operculum; *c*, serrated avicularian mandible; *d*, longitudinal section of zooecia and avicularia. *e-g*, *Porella immersa* n. sp.: *e*, Operculum of ovicelligenous zooecium; *f*, operculum of immature zooecium; *g*, mandible of the frontal avicularium. *h-k*, *Porella acutirostris* Smitt: *h*, Fertile zooecia and ooecia; *i*, operculum, mandible and avicularian gland; *j*, lateral view of zooecia; *k*, distal view of a zooecium. *l-o*, *Porella concinna* (Busk): *l*, Frontal view of zooecia and ooecia; *m*, operculum; *n*, mandible of a subopesia avicularium; *o*, distal view of a zooecium. *p-r*, *Porella kurilensis* n. sp.: *p*, Frontal view of young zooecia; *q*, calcified zooecia; *r*, opercula.



34. *Porella acutirostris* Smitt, 1867Fig. 10*b-k*

Zoarium encrusting, disciform, irregular. Zooecia elongate-hexagonal or oval, separated by salient threads. Frontal slightly convex, smooth or granular, with five to eight pairs of areolar pores, more or less reticulate in appearance. Orifice semicircular, somewhat straight proximally, surrounded by thin, raised, collar-like peristome. Avicularium is median, suboral, acute, on a prominent umbo including broad chamber (10*i*). Ooecia large, prominent, globose, granulate but imperforate. Two distal and two lateral multiporous rosette plates (10*j, k*). Operculum (10*i*) semicircular with muscular attachment. Mandible (10*i*) triangular, blunt, with thin marginal sclerite.

SPECIMENS EXAMINED: No. 575 (Kamtschatka), No. 4000 (Paramushir).

35. *Porella marukawai* Okada, 1918

Zoarium encrusting, unilamellar. Zooecia hexagonal or elongate-quadrangular, usually arranged in quincunx. Frontal wall thick, reticulate in appearance with shallow infundibuliform pores. Orifice nearly circular with shallow sinus limited with a pair of minute condyles. Orificial margin raised proximally into the suboral avicularian umbo supporting a small median avicularium with semicircular mandible. Ooecia large, globular, a little broader than long, distinctly descending proximally into the orifice. The surface divided by a transverse line, the proximal half with scattered pores of irregular shape and size.

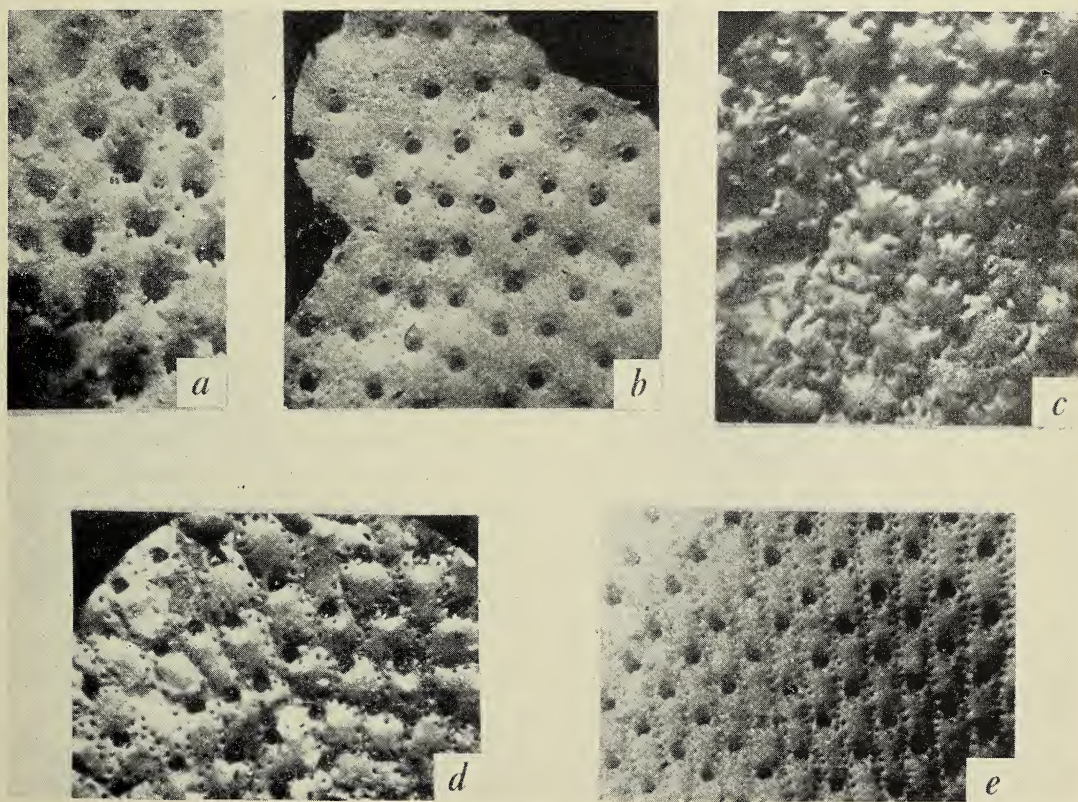


FIG. 11. Photomicrographs of calcined specimens of: *a*, *Porella mucronata* n. sp.; *b*, *P. immersa* n. sp.; *c*, *P. concinna* (Busk); *d*, *e*, *P. kurilensis* n. sp.



SPECIMEN EXAMINED: No. 572 (Kamtschatka).

36. *Porella concinna* (Busk), 1854

Figs. 10*l-o*, 11*c*

Zoarium encrusting, thin, opaque. Zooecia ovate, convex, granular with areolar pores. Zooecial margin more or less sinuate. Orifice orbicular, more or less straight proximally, with distinct lyrula. Peristome thick, high, enclosing zooecial orifice at its bottom. A median suboral avicularium circular or elliptic, within the lower margin of the peristome, sometimes hidden by avicularian umbo. Ooecia globose, often half immersed, rarely with median pore. Operculum transversely elliptic with slightly concave proximal margin; mandible semicircular, typical with median fenestrae.

SPECIMENS EXAMINED: No. 4010 (Paramushir), No. 4208 (Samani), Nos. 4237, 4515 (Akkeshi).

37. *Porella kurilensis* sp. nov.

Figs. 10*p-r*, 11*d, e*

Zoarium encrusting, irregular, thin, delicate. Zooecia quadrangular or hexagonal, granular, convex, five to eight areolar pores on each side. Orifice subcircular, transverse with concave, proximal margin. Peristome thin, slight. Avicularian umbo with transverse inner chamber just proximal to the orifice, supporting a circular or oval avicularium. A distal and two pairs of lateral pore-chambers with multiporous rosette plates. Operculum (10*r*) semi-elliptic, with incomplete marginal thickenings; mandibles minute, semicircular. Ooecia prominent, globose without perforations. The species is similar to some other *Porella*, but differs from them all in its operculum and mandibles.

SPECIMENS EXAMINED: Nos. 1424, 4010B (Paramushir).

38. *Smittina bella* (Busk), 1860

Figs. 12*a-e*, 13

Zoarium moderately thick, encrusting, irregular. Zooecia hexangular, or elongate-quadrangular, convex, granular, punctured. Orifice semicircular or elliptic, transverse, at the bottom of the rather deep peristome with rounded orifice. A proximal median lyrula small, supporting an elliptic operculum. A suboral avicularium median, small, on the raised part with inner transverse cavity. Operculum (12*d*) elliptic. Mandible (12*e*) spatulate, quadrangular. Ooecia globose, immersed, not punctate. Two distal and four lateral rosette plates (12*c*) with narrow tubular passages (12*b*) are figured.

SPECIMENS EXAMINED: No. 1401 (Alaid); No. 1430 (Paramushir); Nos. 4003B, 4008B (Paramushir); No. 4218 (Samani); No. 6261 (Kushiro).

39. *Parasmittina trispinosa* (Johnston), 1825 var.

Fig. 12*f, g*

Zoarium encrusting, irregular, thin. Zooecia hexagonal or quadrangular with salient separating threads. Frontal smooth or granulate, slightly convex, with five to eight areolar pores. Orifice circular, imbedded in the shallow peristome, with lyrula and small cardelles (12*g*). Peristomial orifice circular often raised distally, with two or three distal spines. Avicularia oval, rather large with hinge bar situating laterally or proximally on the frontal. Operculum circular with nearly straight proximal border, mandible is spatulate, or semi-elliptic. The specimen at hand differs slightly from the typical species and from other known varieties.

SPECIMEN EXAMINED: No. 4003D (Paramushir).

40. *Mucronella peachii* (Johnston), 1847

Figs. 12*b, 13*

Zoarium thick, disciform, pale brownish. Zooecia distinct, oval or hexagonal, convex, smooth or granular with prominent suboral mucro and small number of areolar pores.

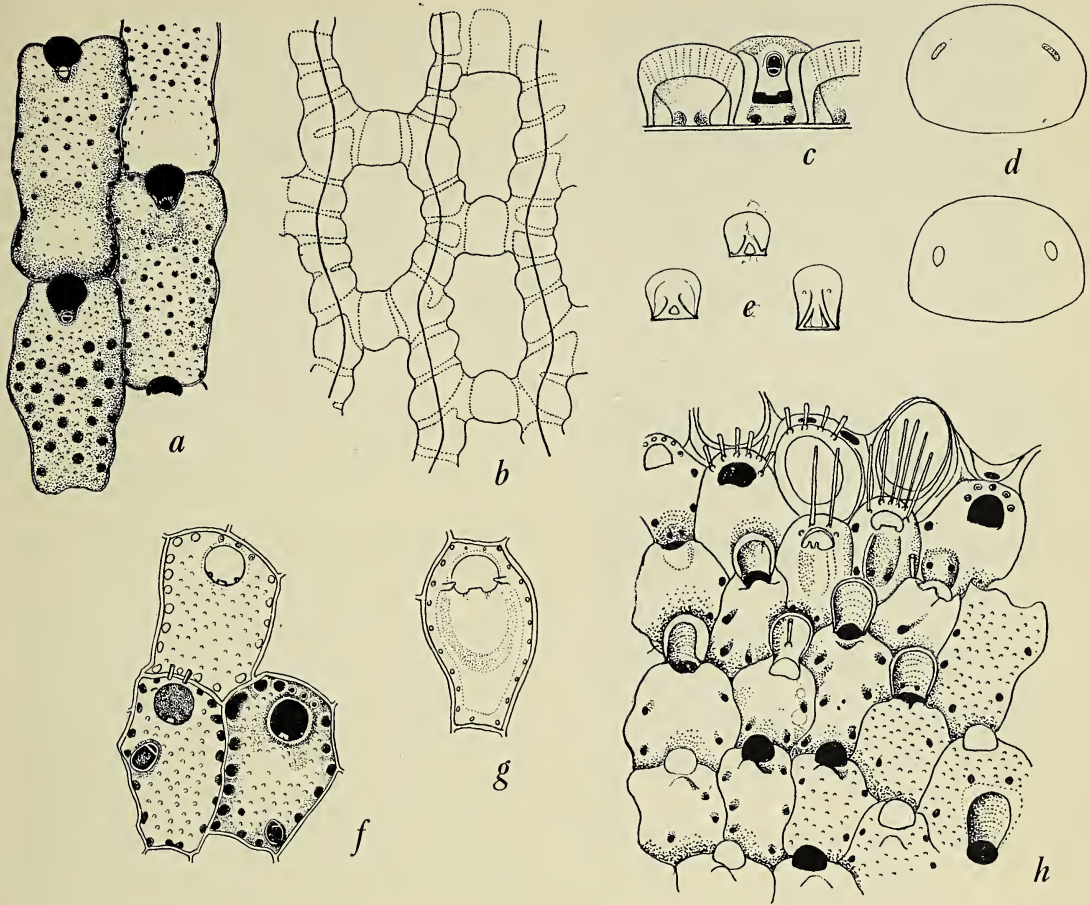


FIG. 12. a-e, *Smittina bella* (Busk): a, Zooecia with immersed oecia; b, basal view of zooecia indicating communication system; c, distal view of zooecia; d, opercula; e, mandibles of peristomial avicularia. f, g, *Parasmittina trispinosa* (Johnston) var.: f, Frontal view of young zooecia; g, internal aspect of a zooecium. h, *Mucronella peachii* (Johnston), frontal view of the growing margin of a colony indicating the development of the oecia, forming of the peristome and the disappearance of the spines.

Orifice semi-elliptic, rather large, straight proximally, with median lyrula. Peristome developed, thick, covering the orifice. Six spines on the distal border of the orifice, long, articulated basally. A longitudinal depressed area at the middle of the frontal, later covered by mucro. Two distal and four lateral multiporous rosette plates. Ooecia globose, half immersed.

SPECIMEN EXAMINED: No. 4003A (Paramushir).

Family RETEPORIDAE

41. *Schizoretepora tumescens* (Ortmann), 1890

Fig. 14a-g

*Retepora tumescens* Ortmann (1890).

Zoarium of usual *Reteporella* type, rather thick, with small elliptic fenestrae. Zooecia facing internally to the cup-shaped colony, elongate-hexagonal, convex, granulate, with



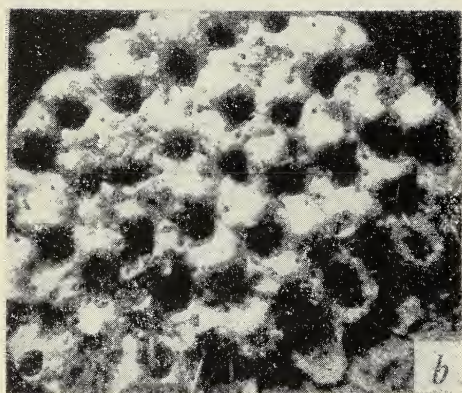
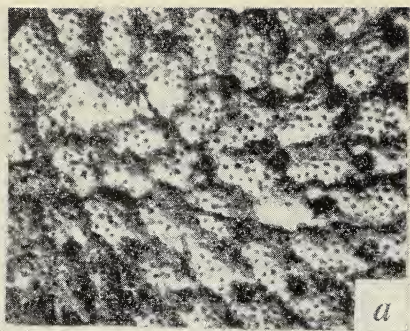


FIG. 13. Photomicrographs of calcined specimens of: *a*, *Smittina bella* (Busk); *b*, *Mucronella peachii* (Johnston).

two to five small pores. Orifice circular, with shallow sinus. Peristome thin collar-like in younger stage (14*c*), thickened with age (14*a*), sinuate or bilobed proximally. Frontal avicularium large, prominent, raised on the mucronate process, with curved end. Ooecia globose (14*b*), distinctly sinuate frontally, smooth. A pair of spines on the distal corner of the peristome. Dorsal vibices (14*e*) salient, limiting elongate quadrate or irregular area. Dorsal avicularia small, elliptic, acute, variable in number. Fenestral perforations rather constant. Operculum (14*f*) subcircular with marginal thickening, mandible (14*g*) triangular, elongate, sometimes with gland, those of dorsal avicularia minute but of the same shape.

SPECIMENS EXAMINED: No. 4009B (Paramushir), No. 4215 (Samani).

#### Family CELLEPORIDAE

##### 42. *Siniopelta costazii* (Audouin), 1826

Zoarium encrusting or discoidal mass. Zooecia decumbent, erect, irregularly crowded. Orifice suborbicular with long sinus, deeply immersed within the peristome. Peristome salient, with erect avicularian processes laterally. Interzooecial avicularia large, scattered, with spatulate mandible. Ooecia decumbent, rounded, broad, with perforated area.

SPECIMENS EXAMINED: No. 1414 (Alaid), No. 1433 (Paramushir), No. 4210 (Samani), No. 4224 (Akkeshi), No. 6288 (Kushiro).

##### 43. *Siniopelta incrassata* (Lamarck), 1856

Fig. 15*a-e*

Zoarium nodulous. Zooecia large, decumbent or erect, piled up in older stage, porous. Zooecial orifice circular with sinus rather longer than wide. Peristome thick, developed; orifice circular, sinuate, with small lateral avicularia on a projection. Ooecia moderate, decumbent, globose, smooth, with perforated frontal. Operculum (15*b*) oval with proximal lip, mandible of dependent avicularium (15*e*) is small, semi-elliptic. Vicarious avicularia occur in two forms, elliptic or circular, with spatulate (15*c*) or semicircular (15*d*) mandibles.

This species is here transferred from *Cellepora*.

SPECIMENS EXAMINED: No. 4020B (Paramushir), No. 4202 (Samani), No. 4231 (Akkeshi), Nos. 6255, 6311 (Kushiro).

#### Family MYRIOZOIDAE

##### 44. *Myriozoom subgracile* d'Orbigny, (1852)

Fig. 15*f-i*

Zoarium erect, tubular, branched, ramose. Zooecia arranged radially around the axis, not distinctly separated. Frontal (15*f*) slightly convex, perforated. Zooecial cavity (15*b*)

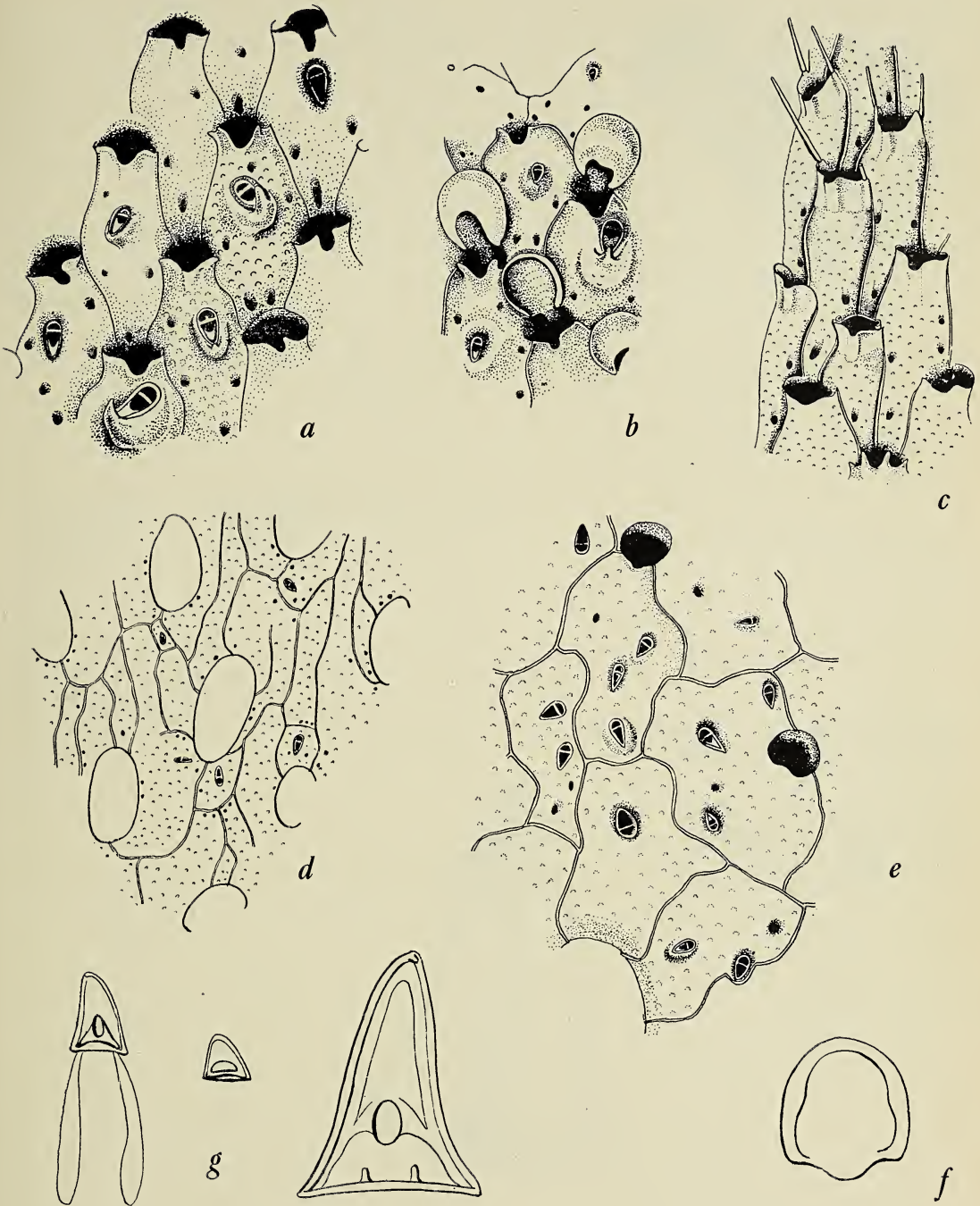


FIG. 14. *Schizoretepora tumescens* (Ortmann): *a*, Frontal view of completed immature zooecia; *b*, fertile zooecia with developing oöcia; *c*, young zooecia near the growing margin; *d*, basal view of a colony; *e*, basal kenozoöcia with basal avicularia; *f*, operculum; *g*, small mandible with avicularian glands and mandible of a gigantic frontal avicularium.



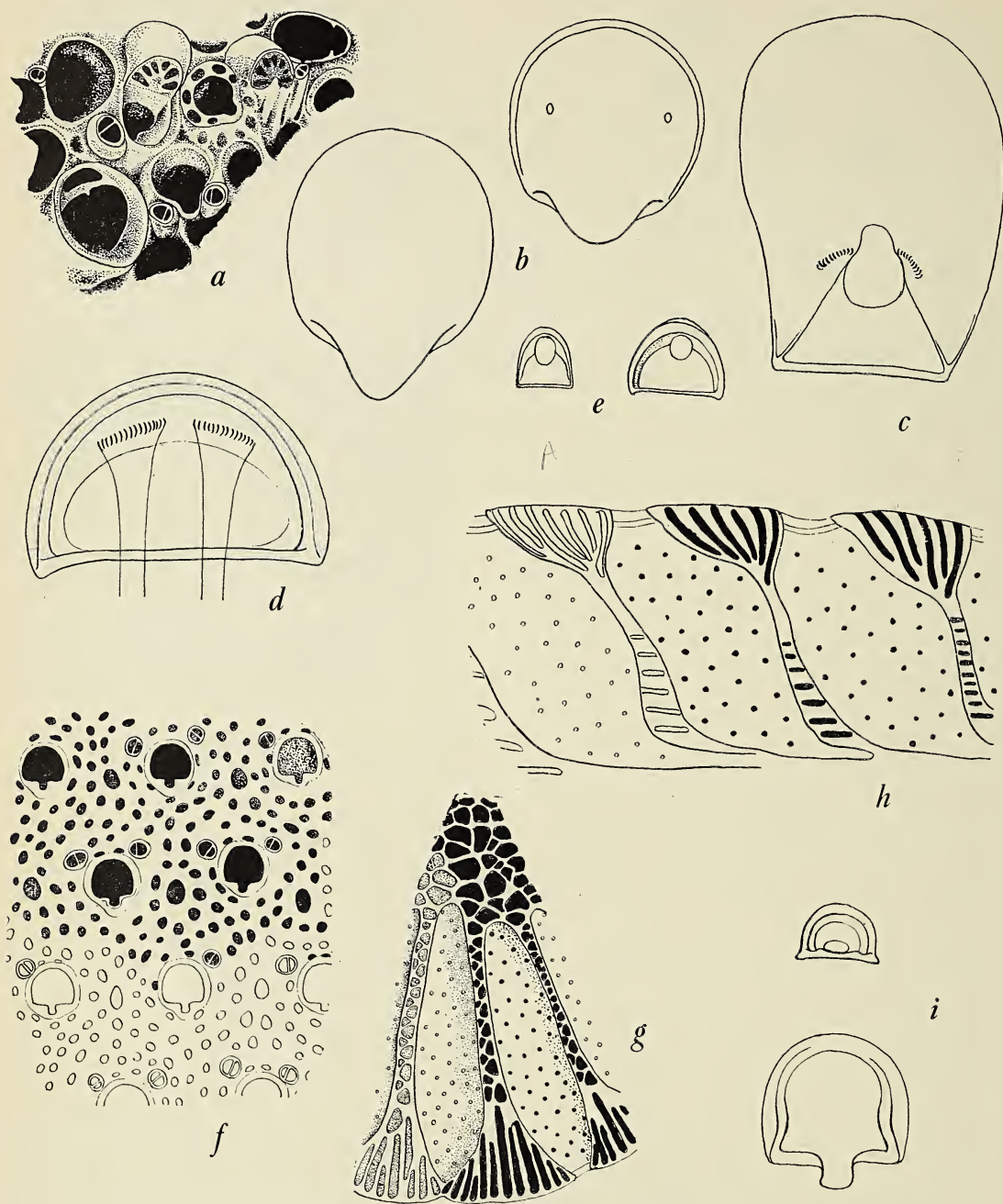


FIG. 15. *a-e*, *Siniopelta incrassata* (Lamarck): *a*, Frontal view of a part of the colony; *b*, opercula; *c*, mandible of a spatulate avicularium; *d*, mandible of a large vicarious avicularium; *e*, mandibles of the frontal avicularia. *f-i*, *Myrizozoum subgracile* d'Orbigny: *f*, Frontal view of a branch; *g*, transverse section of a branch; *h*, longitudinal section of a branch showing numerous communication pores piercing the walls; *i*, operculum and mandible.

deep, communicated by pore-tubes (15*g*) in all directions. Orifice semi-elliptic, with narrow sinus, surrounded by low peristome. Ooecium deeply immersed, obscure in frontal view. Avicularia circular or elliptic, with hinge bar on each distal side of peristome, single or paired. Operculum (15*i*) semi-elliptic, with strong submarginal sclerite and proximal lip. Mandible (15*j*) semicircular with fenestra.

SPECIMENS EXAMINED: No. 4021B (Paramushir), No. 4206 (Samani).

45. *Myriozoella planum* (Dawson), 1859

Zoarium encrusting, uni- or multi-lamellar. Zooecia distinct, slightly convex, distinctly or indistinctly separated. Frontal thick, perforated rather coarsely. Orifice semicircular, with sinus and thickened low peristome. A rounded or elliptic avicularium on each side of the orifice, without hinge bar. Operculum semicircular with marginal sclerite and proximal projection. Mandible semi-elliptic with incomplete marginal sclerite. Ooecia immersed, distinct with marginal pores.

SPECIMENS EXAMINED: No. 1423 (Paramushir), No. 1404 (Alaid), No. 6262 (Kushiro).

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## A Taxonomic Revision of the Hawaiian Species of the Genus *Sophora* Linnaeus (Family Leguminosae)<sup>1</sup>

ALVIN K. CHOCK<sup>2</sup>

THIS PAPER is based upon a study of the endemic Hawaiian species of the genus *Sophora* L. Previous to the present revision, these endemic taxa were identified as: *Sophora chrysophylla* (Salisb.) Seem., *S. chrysophylla* var. *glabrata* (Gray) Rock, *S. grisea* Degener and Sherff, and the taxon *unifoliata* (Rock, 1919: 44) as a variety of *S. chrysophylla* or as a species (Degener and Sherff, in Sherff, 1951: 24).

In addition to these species, there are three introduced species in the Hawaiian Islands: *S. tomentosa* L., *S. japonica* L., and *S. tetraptera* Forst. The latter two were introduced by Rock (1920: 21). These species are not included in this revision.

The plants of Hawaii are noted for polymorphism. This is thought to be due to the isolation and varied ecological habitats of the Hawaiian Islands, and the high endemism (94.4%) of the flora (Fosberg, 1948: 107). St. John (1946: 379–380) has stated that:

Some Hawaiian genera contain species that are homogeneous and widespread, occurring unmodified on all or nearly all of the large islands. . . .

There are other Hawaiian species widespread among the larger islands, but which are not homogeneous, having a tendency to vary. These variations are in part recognized as described

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varieties but in large part are unrecognized, forming a part of the heterogeneous population now included in the species. . . .

Other genera, usually with many species, show a conspicuous segregation into species, usually each species being restricted to a single island or even to a single mountain range or valley on that particular island. . . .

The Hawaiian plants . . . illustrate a progressive series: 1, genera monotypic in Hawaii occurring as invariable wides on all the principal islands; 2, species that are invariable wides, belonging to genera with several Hawaiian species; 3, species that are wides, but showing variability on the various islands; and 4, general [sic] with many Hawaiian species, typically with different, distinct species on each island. These species represent degrees of increasing differentiation and presumably of decreasing age. They show evidences of speciation.

Application of the modern concept of the subspecific entities in a systematic study of the Hawaiian species of *Sophora* has resulted in a revision which clearly reveals the polymorphism of the species, *S. chrysophylla*. This species is usually found in the dry forests from almost sea level to an altitude of 10,000 feet (Rock, 1920: 121). It is also found in two localities in the rain forest at altitudes of 4,000 feet. In the dry forest it is usually the dominant species, and as such is very common on the younger islands of Maui and Hawaii. Its habit may vary from a shrub about 2 meters high to a tree 12 meters high.

The Hawaiians used the wood of this spe-

cies, which they called mamane (sometimes incorrectly spelled mamani), in making house posts (Brigham, 1908: 84); the runners of holua sleds; and the digging stick, the o'o, which was also used as a club and spear in time of war (Malo, 1951: 21). Ranchers on the island of Hawaii use the wood for fence posts, since mamane wood is very hard and durable (Hillebrand, 1888: 109; Rock, 1913: 189; Hosaka and Ripperton, 1944: 60).

*Sophora chrysophylla* is valuable in the Hawaiian Islands in the formation of the "dry forest" and in the prevention of soil erosion and excessive dessication of the soil. It is associated with species of *Acacia*, *Diospyros*, *Dodonaea*, and *Myoporum* on the island of Hawaii (Webster, 1951: 52), where it is most abundant. The seeds of mamane retain their viability for a long period of time and this property should prove useful in reforestation (Akamine, 1951: 45).

#### Acknowledgements

Dr. Harold St. John suggested a revision of this genus and directed my work. Research facilities of the Bernice P. Bishop Museum were made available by Miss Marie Neal. Other institutions (see Abbreviations), including the University of Michigan, graciously provided research facilities or loaned specimens. Dr. M. L. Lohman and Mr. A. R. H. Lamberton of the University of Hawaii assisted in the collections made on the island of Hawaii. Mr. James K. K. Park of the University of Hawaii illustrated the specimens, and Professor Harley H. Bartlett of the University of Michigan supplied the Latin diagnoses.

#### TAXONOMIC RESUMÉ

The genus *Sophora* was described by Linnaeus in *Genera Plantarum* (1754: 175), based on six species (1753: 373–374): *S. alopecuroides*, *S. tomentosa*, *S. heptaphylla*, *S. genistoides*, *S. tinctoris*, and *S. lupinoides*.

Salisbury (1808: 295–300) established the genus *Edwardsia*, segregating from the genus *Sophora*: *E. microphylla*, from *S. microphylla*

and *S. tetraptera*; *E. grandiflora*, from *S. tetraptera*; and described *E. chrysophylla* from a specimen collected by Dr. A. Menzies, botanist on Capt. Vancouver's expedition, presumably from Hualalai, on the island of Hawaii (Wilson, 1920: 162).

Seemann (1865: 66) reduced *Edwardsia* to a section in the genus *Sophora*. Since that time, the Hawaiian species *chrysophylla* has generally been placed in the genus *Sophora*.

Gray (1854: 459) described the variety *glabrata* under *E. chrysophylla*, which was later transferred by Rock (1919: 42–44) to *Sophora*. Hillebrand (1888: 108–109) treats the *Sophora* of Hawaii as one species, without a variety, although he cites Gray as a reference, and notes that the "lower forms are nearly glabrate and bear smaller flowers." Rock (1919: 44) established a new variety, *unifoliata*, from Puu Waawaa, Hawaii.

Until 1951 Degener (in Sherff, 1951: 24) continued to classify mamane under the genus *Edwardsia*, and in 1932 (1932: fam. 169c) raised the var. *unifoliata* to a species (*E. unifoliata* (Rock) Degener). Degener and Sherff (Sherff, 1951: 24) later transferred this species to the genus *Sophora*. In the same paper, *S. grisea* Degener and Sherff was described from collections made by Degener and Greenwell on the island of Oahu.

#### RELATIONSHIPS OF THE GENUS

The genus *Sophora* consists of more than 25 species, distributed over the warmer regions of both hemispheres, which are found in Asia, South America, the southwest United States, New Zealand, the islands of the South Pacific Ocean, and Hawaii (Rock, 1913: 187).

Our species is a member of the section *Edwardsia*, which is characterized by the four-winged pods, and it is related to *S. tetraptera* Forst. of New Zealand, *S. macrocarpa* Sm. and *S. microphylla* Sol. in Ait. of Peru and Chile, *S. denudata* Bory of Réunion, *S. mollis* Grah. and *S. interrupta* Bedd. of India. *Sophora* is placed in the subfamily *Papilionatae*, and in the tribe *Sophoreae*.



## TAXONOMICALLY USEFUL CHARACTERS

*S. chrysophylla* is a polymorphic species comparable to *Myoporum sandwicense* Gray, which has been treated by Webster (1951). It has been extremely difficult to find morphological characters which do not vary among the plants in a given area; even among the various taxa proposed in this revision, there are both similar and dissimilar characters among the individuals of each taxon. After study, it seemed that a valuable character might be the shape (ovate, obovate, circular, and elliptic) of the standard, which is more or less the same for each plant of the various populations. This is used to define the subspecies.

The shape of the apex and base of the standard, wing, and keel petals; the margin of the wing and keel petals; and the shape and pubescence of the leaflets are used to define the variety, subvariety, and form.

Except in two subvarieties (*ovatifoliolata* and *grisea*), the characteristic leaflet shape is oblong-obovate. The pubescence is strigose, and ranges from abundant to none, and from golden brown to silver. The upper surface ranges from being abundantly pubescent to glabrate. The lower surface is more pubescent than the upper surface.

The calyx tube is usually goblet shaped, and the lobing of the tube may vary, as well as the degree of the parting of the calyx teeth.

The size of the fruit and the width of the wings may vary greatly. Although certain taxa may be characteristically narrow or wide winged, both of these, as well as intergrading widths, may be found on the same plant. Seed color has been found to be an unreliable character, although all of the seeds of a certain taxon may have the same color. It has been found that a fungus infects the seed coat and produces fruiting structures and mycelia which cause changes in the coloration of the seed coat, especially around the hilum, where a gray-black discoloration may appear, which is surrounded by the characteristic yellow-brown color of most mamane seeds.

Seeds in one collection (Chock, *et al.*, 594) ranged from yellow, to brown, to red, to gray-black.

These characters are somewhat useful in the classification of the subspecific taxa of *S. chrysophylla*. Abundant flowering material is necessary to determine the different taxa because of the variations that occur within that taxon.

## DISTRIBUTION

Collections have been made from the major islands of the Hawaiian group, excepting Kahoolawe and Niihau. However, this species may have occurred on these islands before the dry forest was wiped out by introduced fauna and flora, and erosion.

On the island of Kauai, it is found in the forests of Kokee Territorial Park, at elevations of 3,600 to 4,000 feet. On the island of Oahu, it has been reported or collected from the lee and windward sides of the Waianae Mountains.

On the island of Maui, it is very common on the slopes and in the crater of Haleakala, from 5,000 to 10,000 feet; collections have also been made from the leeward slopes at lower altitudes (1,500 feet). Along the windward slopes, in the rain forest east of Olinda, there is a small population of mamane (4,000 feet). In Olowalu Valley on West Maui, Forbes collected a specimen, the leaflets of which are much smaller than any other known. This material is sterile, however, and has not been rediscovered.

Forbes made a collection from the island of Molokai with a note on the specimen sheet that it was "very rare" on Puu Kolekole. Forbes' collections from Olowalu, Maui, and Puu Kolekole, Molokai, were not included in this revision. On the island of Lanai, Rock (1913: 189) thought that the mamane was planted by man, although this could not be established. G. C. Munro (1954: personal correspondence), a long-time resident of Lanai, however, is of the opinion that it is native to that island.

On the island of Hawaii, it is very common, being one of the dominant endemic species. It is found as such along the slopes of Mauna Loa and Mauna Kea; in the lower forests of the Kau District; and from almost sea level near Puu Waawaa to the slopes of Hualalai. It has also been reported at lower elevations near Milolii by E. Y. Hosaka. Rock (1913: 23) considered this species as the main element in the forest above 3,700 feet. Ripperton and Hosaka (1942: 14) considered it as the dominant species in the "forest formation" from 5,000 feet to the timber line at 10,000 feet, and in the "parkland formation" (zones E<sub>1</sub> and E<sub>2</sub>).

The lowest subspecific taxa proposed in this revision are restricted to definite localities on an island. In some localities, however, several taxa may be present.

#### ABBREVIATIONS

The majority of the specimens which were examined and cited are deposited in the herbarium of Bernice P. Bishop Museum (BISH) in Honolulu, Hawaii. Specimens deposited elsewhere are indicated by the use of the following abbreviations (Lanjouw and Stafleu, 1954):

BM—British Museum of Natural History; F—Chicago Natural History Museum; GH—Gray Herbarium of Harvard University; NY—New York Botanical Garden; US—U. S. National Museum, Smithsonian Institution.

The completeness of the specimens cited is indicated by the following abbreviations: bd.—bud; lv.—leaves; fl.—flower; fr.—fruit; st.—stem; wood—wood specimen collected by A. R. H. Lamberton.

#### SYSTEMATIC TREATMENT

##### Genus *SOPHORA* Linnaeus

*Sophora* Linnaeus, Species Plantarum, 373, 1753; Genera Plantarum, 175, 1754.

*Edwardsia* Salisbury, Linn. Soc., Trans. 9: 296–300, 1808.

Shrub to tree; leaves usually pinnate; leaflets usually small and numerous; flowers in simple, terminal racemes or several forming a terminal panicle; calyx cupshaped, with short teeth; corolla yellow, white, rarely purple; standard obovate, elliptic, ovate or orbicular, often shorter than the keel, rarely longer; wing usually oblong, shorter than the keel; stamens free or rarely connected at the base in a ring, with dorsifixed anthers; ovary with many ovules; pod cylindrical to somewhat flattened, often constricted between the seeds, often four-winged (in the section *Edwardsia*), fleshy or woody, usually indehiscent; seeds ovoid or globose.

TYPE SPECIES: *Sophora tomentosa* L. has been chosen as the lectotype of the genus (Camp, et al., 1947: 117).

##### Section EDWARDSIA (Salisbury) Seemann

*Edwardsia* Salisbury, Linn. Soc., Trans. 9: 296–300, 1808 (as a genus).

*Edwardsia* (Salisb.) Seem., Flora Vitiensis, 66, 1865 (as a section).

Fruit constricted between the seeds, with four longitudinal wings on the pod. Leaves usually pinnate, without stipules.

1. *Sophora chrysophylla* (Salisb.) Seem., Flora Vitiensis, 66, 1865

*Edwardsia chrysophylla* Salisb., Linn. Soc., Trans. 9: 299; tab. 26, fig. 1, 1808.

Shrub to tree, 2–12 meters high, diameter 2–9 dm.; branches longitudinally ridged, the younger branches brown, with abundant golden brown strigose pubescence, becoming gray-black, and silver and glabrate, the older branches glabrous, the ridges not as deep as on the younger branches; leaves alternate, usually pinnate, rarely unifoliolate, bifoliolate, or trifoliolate; leaflets usually opposite and usually oblong-obovate, sometimes broadly elliptic to oblong to oblong-ovate, 3–23 mm. broad, 7–50 mm. long, the apex obtuse to retuse, the base cuneate, the lower surface



usually abundant golden brown strigose, becoming silver, the upper surface glabrate; petiolule 0.5–2 mm. long; rachis-petiole length up to 17 cm., moderately to deeply channeled along the rachis; flowers in terminal racemes or panicles; pedicels 6–30 mm. long; calyx tube goblet-shaped, five lobed, 5–19 mm. broad, 4–12 mm. high; corolla yellow, glabrous; the standard ovate, obovate, circular, or elliptic, the apex obtuse to retuse, the base obtuse to cuneate, 8–20 mm. broad, 11.5–20 mm. long, reflexed when mature, the claw 3–8 mm. long; the petals of the wings oblong-lanceolate to oblong to elliptic, the apex acute to obtuse to truncate, the base asymmetrical or symmetrical, margin entire or irregularly indented, 3–9.5 mm. broad, 12.5–28 mm. long, the claw 3–5.5 mm. long; the petals of the keel elliptic to oblong to ovate to lanceolate, the apex obtuse to acute, the base asymmetrical or symmetrical, the margin entire or irregularly indented, 3.5–12 mm. broad, 14–25 mm. long, the claw 2–6 mm. long; stamens 10, the anthers golden brown, dorsifixed; pistil recurved, abundantly covered with golden brown hairs, with a small terminal stigma; pods 2–16 cm. long, 5–18 mm. broad, including the wings, which are 1–7 mm. wide, tan, but often with a fungus giving the mature fruits a black appearance, abundant to sparse golden brown strigose, becoming silver and glabrate, constricted between the seeds, with four longitudinal wings; seeds oblong-ovoid, ovoid or globose, moderately compressed, golden brown to orange to gray-black, 3–6 mm. wide, 4.5–8 mm. long, 2–4.5 mm. thick.

#### KEY TO THE SUBSPECIES OF *S. chrysophylla*

- A. Standard obovate or ovate. . . . . B
- A. Standard circular or elliptic. . . . . C
- B. Standard obovate. (2). ssp. **chrysophylla**
- B. Standard ovate. . . . . (8). ssp. **glabrata**
- C. Standard circular. . . (27). ssp. **circularis**
- C. Standard elliptic. . . (30). ssp. **unifoliata**

#### 2. *Sophora chrysophylla* ssp. **chrysophylla** Figs. 1*d*, 5

*Sophora chrysophylla* (Salisb.) Seem., Flora Vitiensis, 66, 1865.

*Edwardsia chrysophylla* Salisb., Linn. Soc., Trans. 9: 299; tab. 26, fig. 1, 1808.

Tree, 4–8.3 meters high; leaves pinnate; leaflets oblong-obovate, 5–17 mm. broad, 10–34 mm. long; rachis-petiole up to 12 cm. long; pedicels 8–23 mm. long; calyx tube 5–13 mm. broad, 5–12 mm. high; the standard obovate, the base cuneate; the petals of the wing 6–9 mm. broad, 16–28 mm. long, the

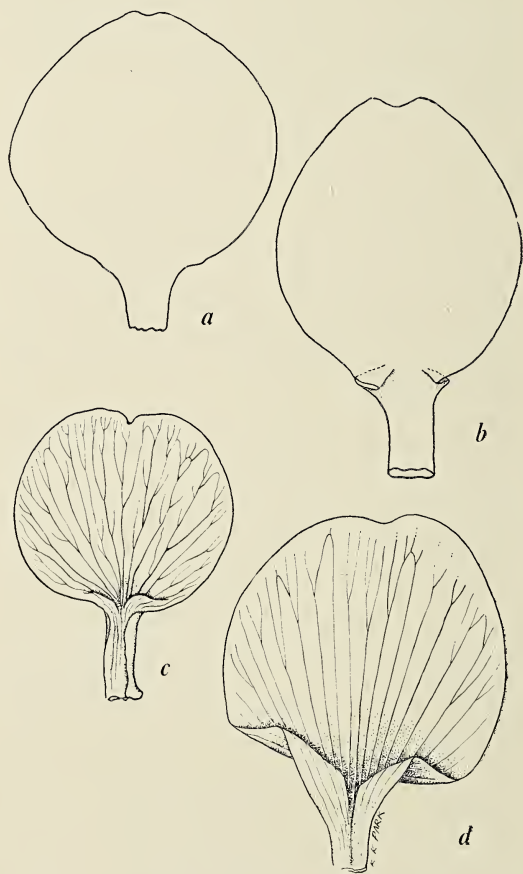


FIG. 1. Standard,  $\times 2$ : *a*, ssp. *glabrata*, Chock et al. 577; *b*, ssp. *unifoliata*, Degener et al. 19, 327; *c*, ssp. *circularis*, Chock et al. 749; *d*, ssp. *chrysophylla*, Chock et al. 575.

base truncate, but sometimes truncate on one side and cuneate or sagittate on the other side; the petals of the keel 3.5–10 mm. broad, 16.5–23 mm. long; pods 3.1–13 cm. long, including the beak, which is 4–28 mm., 8–15 mm. wide, including the wings, which are 1–4 mm., 1–8 seeded; seeds golden brown to brown to gray-black.

KEY TO SUBSPECIES *chrysophylla*

- A. Width of standard under 10 mm., oblong-obovate.....7. var. **makuaensis**
- A. Width of standard over 10 mm., broad obovate.....B. (3. var. **chrysophylla**)
- B. Rachis-petiole length always under 6.5 cm.; pedicels 15–23 mm. long.....5. f. **haleakalaensis**
- B. Rachis-petiole length always over 6.5 cm.; pedicels 8–16 mm. long.....C
- C. Margin of keel irregularly indented, the apex obtuse.....6. f. **obovata**
- C. Margin of keel entire, the apex acute....4. f. **chrysophylla**

3. *Sophora chrysophylla* ssp. *chrysophylla* var. *chrysophylla*

*Sophora chrysophylla* (Salisb.) Seem., Flora Vitiensis, 66, 1865.

*Edwardsia chrysophylla* Salisb., Linn. Soc., Trans. 9: 299; tab. 26, fig. 1, 1808.

The standard obovate, the apex retuse, 16–18 mm. broad, 11.5–18 mm. long.

4. *Sophora chrysophylla* ssp. *chrysophylla* var. *chrysophylla* f. *chrysophylla*

Figs. 1*d*, 2*f*, 3*f*, 4, 5

*Sophora chrysophylla* (Salisb.) Seem., Flora Vitiensis, 66, 1865.

*Edwardsia chrysophylla* Salisb., Linn. Soc., Trans. 9: 299; tab. 26, fig. 1, 1808.

Pedicels 10–15 mm. long; calyx tube 10–13 mm. broad, 7–8 mm. high; the petals of the wing elliptic, the apex obtuse, the base truncate, 9 mm. broad, 16 mm. long; the petals

of the keel elliptic, the base truncate on one side and sagittate on the other side, the apex acute; seeds brown.

SPECIMEN TYPICUM: "Insulis Sandwich, legit *A. Menzies*." (BM—examined by R. S. Cowan of the New York Botanical Garden).

SPECIMENS EXAMINED: **Hawaii**, Hualalai—just below summit, west slope, above Puu Laalau, about 7,500 feet, June 19, 1934,

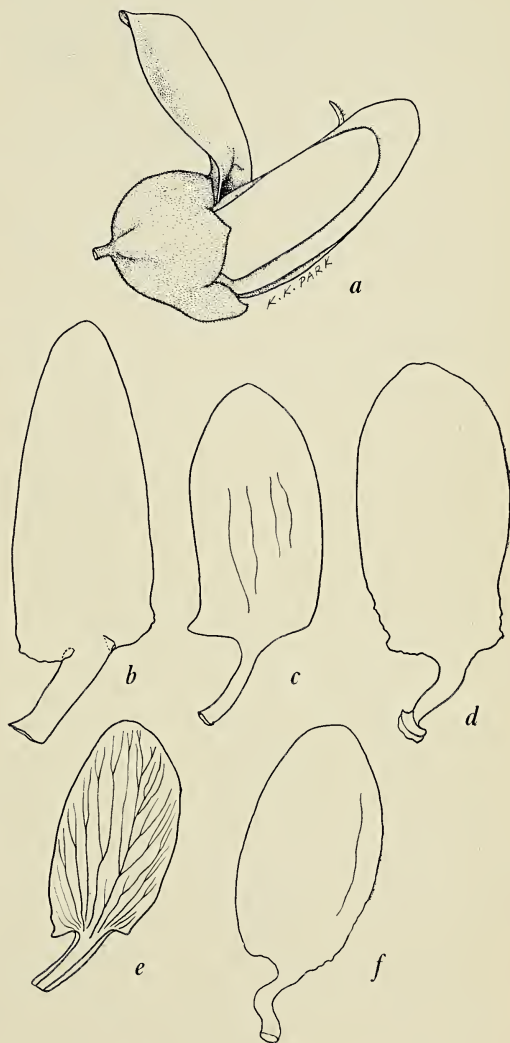


FIG. 2. *a*, Flower,  $\times 2$ : *f. maunakeaensis*, Chock et al. 577. *b-f*, Keel petals,  $\times 2$ : *b*, *f. olindaensis*, Chock et al. 286; *c*, var. *kauensis*, Chock et al. 749; *d*, var. *circularis*, Chock et al. 612; *e*, *f. obtusa*, Chock et al. 584; *f*, *f. chrysophylla*, Neal (June 19, 1934).



*Marie Neal* (st. lv. bd. fl. fr.); slope, 7,000 feet, June 9, 1909, *Rock* (st. lv. bd. fl.); near summit, June 19, 1911, *Forbes 217H* (BISH, NY) (st. lv. fr.).

5. *Sophora chrysophylla* ssp. *chrysophylla*  
var. *chrysophylla* f. *haleakalaensis*, forma  
nov.

Figs. 4, 5

Rachide cum petiolo quam 6.5 cm. breviori; pedicellis 15–23 mm. longis; vexillo late obovato, 18 mm. lato, 16 mm. longo; petalis carinae oblonge ellipticis, apice retusis, basi uno latere truncatis altero sagittatis.

Rachis-petiole up to 6.5 cm. long; pedicels 15–23 mm. long; calyx tube 5 mm. wide and 12 mm. high; the standard broad obovate, 18 mm. broad, 16 mm. long; the petals of the

wing oblong, the apex acute, the base truncate on one side and sagittate on the other side, 7 mm. broad, 17 mm. long; the petals of the keel oblong-elliptic, the apex retuse, the base truncate on one side and sagittate on the other side, 8 mm. broad, 23 mm. long; seeds brown.

TYPE: **Maui**, Haleakala crater, small ravine opposite Ka moa o Pele, August 4, 1938, *Hawaiian Bog Survey 2798* (Cranwell, Selling, and Skottsberg) (BISH) (st. lv. bd. fl.).

SPECIMENS EXAMINED: **Maui**, Haleakala—crater, Aug., 1910, *Forbes 289M* (BISH, NY) (st. lv. bd. fr.); 1909, *Brigham, Anderson and Hosmer* (st. lv. fr.); west slope, 8,000 feet, May, 1911, *Rock*; near Koolau gap within crater, June 29, 1927, *Degener 17,948* (NY) (st. lv. bd. fr.); crater, 6,000 to 10,000 feet, Oct. 2–5, 1916, *Hitchcock 14,967* (US) (st. lv. bd. fl.); south side of Red Hill, 8,500 feet, Nov. 24, 1950, *Degener, et al.*, 21,112 (F) (st. lv. bd. fr.).

This form is so named because it occurs on Haleakala.

6. *Sophora chrysophylla* ssp. *chrysophylla*  
var. *chrysophylla* f. *obovata*, forma nov.

Figs. 1d, 4, 6a, b

Rachide cum petiolo quam 10.5 cm. breviori; vexillo obovato, 16 mm. lato, 19 mm. longo; petalis carinae ellipticis, apice obtusis, basi truncatis, margine prope basin irregulariter indentatis.

Rachis-petiole up to 10.5 cm. long; the standard obovate, 16–18 mm. broad, 17–18 mm. long; the petals of the keel elliptic, the apex obtuse, the base truncate, the margin irregularly indented toward the base, 9–10 mm. broad, 19–20 mm. long; seeds golden brown.

TYPE: **Hawaii**, Mauna Kea, south slope, 3.6 miles north of Humuula, Hale Pohaku-Humuula road, Aug. 30, 1952, *Chock, Lohman and Lamberton 575* (BISH) (wood, st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: **Hawaii**, Mauna

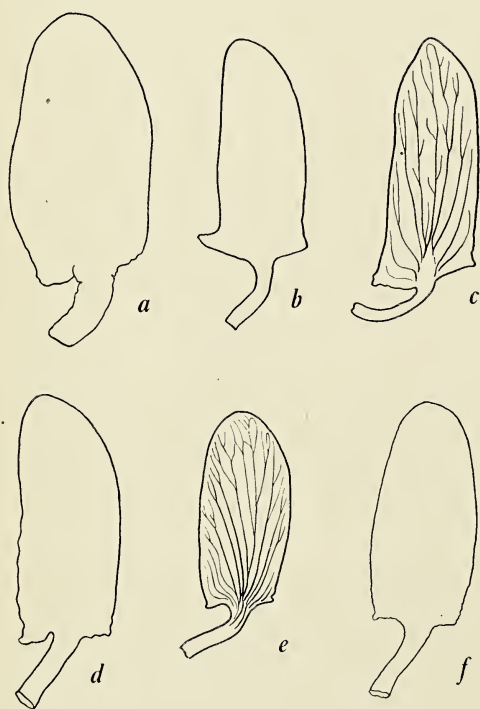


FIG. 3. Wing petals,  $\times 2$ : a, f. *maniensis*, Chock et al. 283; b, var. *kauensis*, Chock et al. 749; c, f. *puuwaawaaensis*, Chock et al. 799; d, var. *circularis*, Chock et al. 612; e, f. *obtusa*, Chock et al. 584; f, f. *chrysophylla*, Neal (June 19, 1934).

Kea, south slope, Aug. 30, 1952, *Chock, et al.*, 579 (st. lv. bd. fl.).

This form is named for the obovate standard petal.

7. *Sophora chrysophylla* ssp. *chrysophylla*  
var. *makuaensis*, var. nov.

Figs. 4, 6c, d

Vexillo oblonge obovato, fere truncato, 8 mm. lato, 20 mm. longo.

Rachis-petiole up to 8 cm. long; pedicels 10–20 mm. long; the standard oblong-obovate, the apex obtuse, almost truncate, 8 mm. broad, 20 mm. long; the petals of the wing oblong-lanceolate, the base truncate on one side and cuneate on the other side, 6 mm. broad, 28 mm. long; the petals of the keel ovate-oblong, the apex obtuse, the base truncate on one side and cuneate on the other side, 3.5 mm. broad, 16.5 mm. long; pods 8–9.5 cm. long, the wings 1–2 mm. wide, 6–8 seeded; seeds gray-black.

TYPE: Oahu, Waianae Mountains, Makua, Nov. 1929, *Russ* (BISH), 4 sheets (st. lv. bd. fl. fr.).

C. S. Judd (1930(1): 12), former territorial forester, remarks in his report for December, 1929: "I discovered a clump of Mamani [sic] trees (*Sophora chrysophylla*) near the center of Makua Valley. Previously this tree was known only at Ohikilolo. The beautiful yellow blossom were long and slim. . . ."

This variety is so named because it occurs in Makua Valley, Oahu.

8. *Sophora chrysophylla* ssp. *glabrata*  
(Gray), comb. nov.

Figs. 1a, 7, 8

*Sophora chrysophylla* var. *glabrata* (Gray) Rock, Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry, Bot. Bul. 5: 42–44, 1919.  
*Edwardsia chrysophylla* var. *glabrata* Gray, U. S. Expl. Exped., Botany, Phanerogamia 1: 459–460, 1854.

HAWAIIAN ISLANDS ASSEMBLED

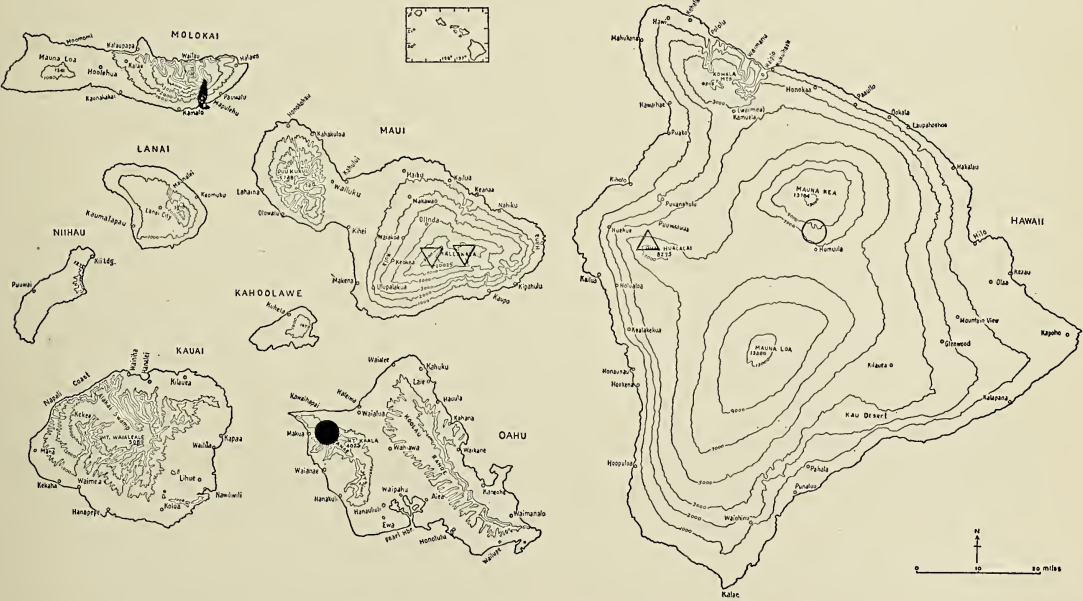


FIG. 4. Map of distribution of *Sophora chrysophylla* ssp. *chrysophylla*. Open erect triangles represent f. *chrysophylla*, open inverted triangles f. *haleakalaensis*, open circle f. *obovata*, solid circle var. *makuaensis*.



Shrub to tree, 2-12 meters high; leaves pinnate, leaflets broadly elliptic to oblong-obovate to oblong to oblong-ovate to oblong-lanceolate; the standard ovate to oblong-ovate, 9-23 mm. broad, 12-18 mm. long; the petals of the wing 3-9.5 mm. broad, 13-21 mm. long, the base usually truncate, the margin sometimes irregularly indented toward the base; the petals of the keel 5-12 mm. broad, 14-22 mm. long, the base usually truncate; pods 2-14.5 cm. long, including the beak, which is 3-20 mm., 5-18 mm. wide, including the wings, which are 0.5-7 mm., 1-8 seeded; seeds golden brown to red-brown to gray-black.

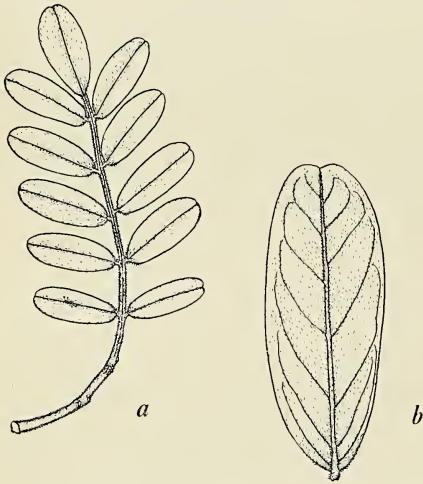


FIG. 5. *F. chrysophylla*, Neal (June 19, 1934): *a*, leaf, upper surface,  $\times 0.5$ ; *b*, 1 after (median lateral), lower surface,  $\times 2$ . Leaflet of *f. balakalaensis*, Rock (May 1911): *c*, upper surface,  $\times 2$ ; *d*, lower surface,  $\times 2$ .

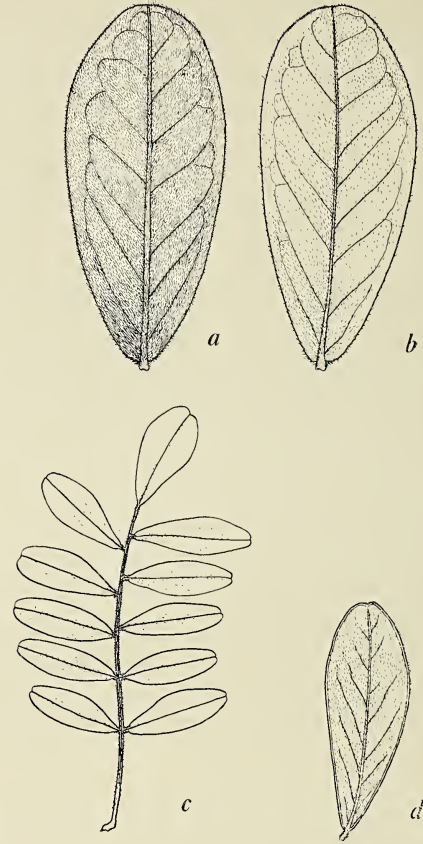


FIG. 6. Leaflet of *f. obovata*, Chock et al. 575: *a*, lower surface,  $\times 2$ ; *b*, upper surface,  $\times 2$ . Var. *makuaensis*; *c*, leaf, upper surface,  $\times 0.5$ ; *d*, leaflet, lower surface,  $\times 1$ .

#### KEY TO SUBSPECIES *glabrata*

- A. Leaflets glabrate . . . . . B
- A. Leaflets abundantly strigose-pubescent. E
- B. Calyx tube 9-11 mm. broad, 4-6 mm. high. . . . . 9. var. *glabrata*
- B. Calyx tube 7-8 mm. broad, 6-9 mm. high. . . . . G
- C. Standard oblong-ovate, length 1.5 times width. . . . . 10. var. *lanaiensis*
- C. Standard ovate, length equal to width, or almost so. . . . . D
- D. Calyx tube 7-7.5 mm. broad, 7-8 mm. high; apex of standard obtuse. . . . . 26. *f. parva*

- D. Calyx tube 8 mm. broad, 6–9 mm. high; apex of standard retuse. . . . . 14. f. *puuwaawaaensis*
- E. Apex of standard retuse. . . . . F. (11. var. *ovata*)
- E. Apex of standard obtuse. . . . . K. (20. var. *grisea*)
- F. Rachis-petiole up to 12 cm. long; largest leaflets 23 mm. broad, 50 mm. long. . . . . G. (12. subvar. *ovata*)
- F. Rachis-petiole up to 17 cm. long; largest leaflets 12 mm. broad, 32 mm. long. . . . . I. (16. subvar. *mauiensis*)
- G. Margin of wing or keel never irregularly indented; leaflets 3–23 mm. broad, 10–50 mm. long. . . . . 13. f. *ovata*
- G. Margin of wing or keel always irregularly indented; leaflets 5–15 mm. broad, 10–34 mm. long. . . . . H
- H. Margin of wing and keel indented; keel and wing base moderately hastate on one side, the other side truncate; lower surface of leaflets glabrate. . . . . 14. f. *puuwaawaaensis*
- H. Margin of keel indented, wing margin entire; keel and wing base truncate; lower surface of leaflets abundantly pubescent. . . . . 15. f. *maunakeaensis*
- I. Base of keel truncate on both sides, symmetrical. . . . . 18. f. *lualailuaensis*
- I. Base of keel truncate on only one side, asymmetrical; or not truncate. . . . . J
- J. Base of keel truncate-oblique, the apex acute. . . . . 17. f. *mauiensis*
- J. Base of keel obtuse to truncate-oblique, the apex obtuse. . . . . 19. f. *olindaensis*
- K. Leaflets usually ovate-oblong. . . . . 26. subvar. *ovatifoliolata*
- K. Leaflets usually obovate-oblong or broadly elliptic. . . . . L
- L. Leaflets broadly elliptic, abruptly cuneate at the base. . . . . 21. subvar. *grisea*
- L. Leaflets oblong to oblong-obovate, the base cuneate. . . M. (22. subvar. *obtusa*)
- M. Base of wing sagittate. . . . . 23. f. *obtusa*
- M. Base of wing not sagittate, but truncate or cuneate, or cuneate on one side and hastate on the other side. . . . . N
- N. Base of wing truncate or cuneate, symmetrical. . . . . 24. f. *maunaloaensis*
- N. Base of wing cuneate on one side and hastate on the other side, asymmetrical. . . . . 25. f. *parva*
9. *Sophora chrysophylla* ssp. *glabrata* var. *glabrata* (Gray) Rock, Hawaii Bd. Com-mrs. Agr. and Forestry, Div. Forestry, Bot. Bul. 5: 42–44, 1919.

Fig. 7

*Edwardsia chrysophylla* var. *B. glabrata* Gray, U. S. Expl. Exped., Botany, Phanerogamia 1: 459–460, 1854.

Rachis-petiole up to 8 cm. long; petiolule 0.5 mm.; leaflets oblong to oblong-obovate, glabrate, 6–10 mm. broad, 13–24 mm. long, upper surface very dark, shiny, lower surface dark, dull; calyx tube 9–11 mm. broad, 4–6 mm. high, pubescent; the standard 13 mm. broad, 9 mm. long, the base obtuse; the petals of the keel oblong, 5 mm. broad, 18 mm. long, the apex acute, the base truncate on one side and cuneate on the other side; fruit 8.5 cm. long, 13 mm. wide, including the wings, which are 3–4 mm.

TYPE: "Sandwich Islands . . . Hawaii, 1,000 feet above Puna," U. S. Expl. Exped., under Captain Wilkes (type, US; isotype, G) (st. lv. fl. fr.).

The variety was obviously named for the glabrate condition of the leaflets. The calyx is not glabrate, however, as stated by Gray



HAWAIIAN ISLANDS ASSEMBLED

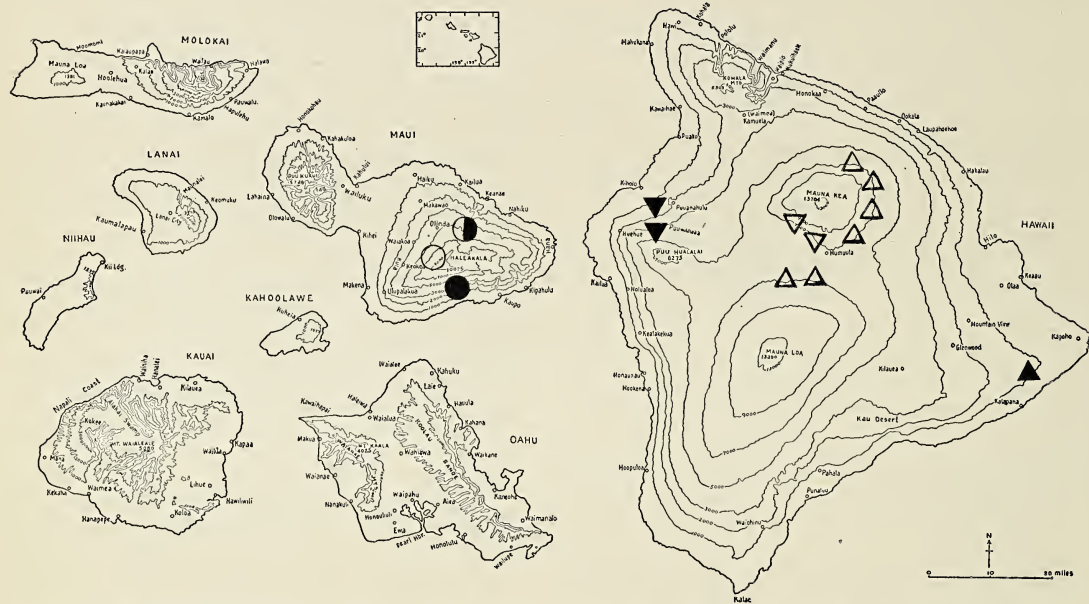


FIG. 7. Map of distribution of *Sophora chrysophylla* ssp. *glabrata*. Solid erect triangle represents var. *glabrata*, open erect triangles f. *ovata*, solid inverted triangles f. *puuwaawaaensis*, open inverted triangles f. *maunakeaensis*, open circle f. *mauiensis*, solid circle f. *lualailuaensis*, half-solid circle f. *olindaensis*.

HAWAIIAN ISLANDS ASSEMBLED

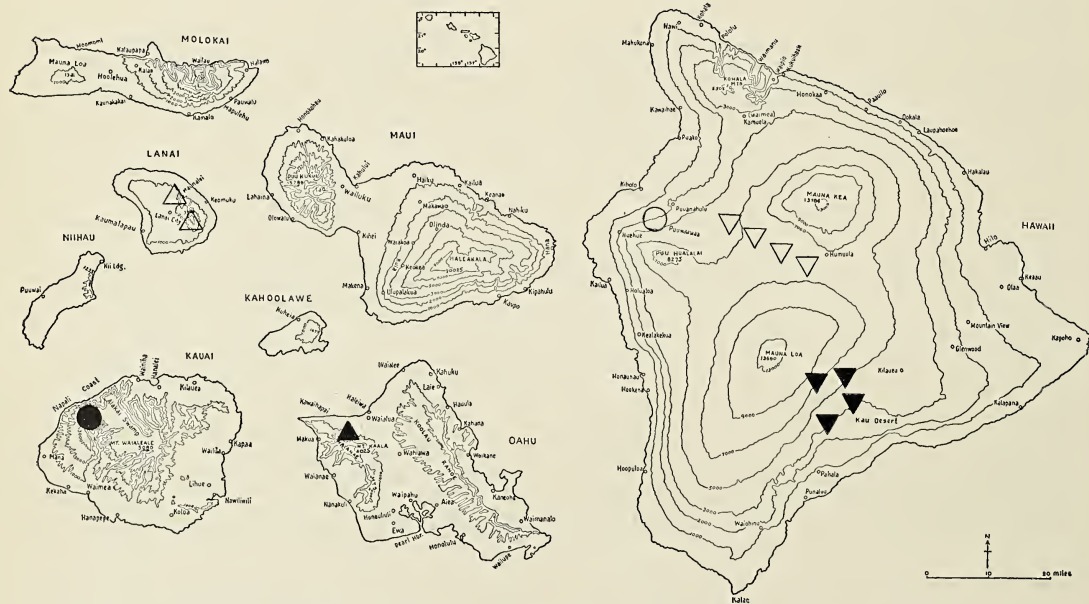


FIG. 8. Map of distribution of *Sophora chrysophylla* ssp. *glabrata*. Open erect triangles represent var. *lanaiensis*, solid erect triangle subvar. *grisea*, open inverted triangles f. *obtusata*, solid inverted triangles f. *maunaloaensis*, open circle f. *parva*, solid circle subvar. *ovatifoliolata*.

(1854: 459). He mentions that "the flowers are rather smaller."

10. *Sophora chrysophylla* ssp. *glabrata*  
var. *lanaiensis*, var. nov.

Figs. 8, 9a, b

*S. chrysophylla* var. *glabrata* (Gray) Rock, sensu Rock, Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry, Bot. Bul. 5: 42-44, 1919.

Vexillo oblonge ovato, 9 mm. lato, 13 mm. longo.

Leaflets 4-11 mm. broad, 15-30 mm. long; calyx tube 7-8 mm. broad, 7-9 mm. high; the standard oblong-obovate, 9-13 mm. broad, 13-20 mm. long; the petals of the wing oblong-lanceolate, the base hastate, but

not symmetrical, the base 5-7 mm. wide, the petals 3-5 mm. broad, 17-21 mm. long; the petals of the keel oblong to oblong-lanceolate, the base obtuse on one side and hastate to cuneate on the other side, 5-8 mm. broad, 19-24 mm. long; the pods 1-5 seeded, the wings 0.5-1.5 mm. wide; seeds gray-black to red-brown.

TYPE: Lanai, "On the plateau leeward side, near Koele, back of Gibson Homestead, flowering and fruiting July 29, 1910, *Rock no. 8012*" (type: BISH; isotypes: G, NY, US) (st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: Lanai—mountains of eastern end, June, 1913, *Forbes 234L* (st. lv. bd. fl. fr.); Kaluanui, Apr. 16, 1919, *Munro* (BISH, NY) (st. lv. bd. fl.); ravine in lower plain, Sept. 21, 1916, *A. S. Hitchcock 14,673* (US) (st. lv. bd. fl.).

Hawaiian Islands, no locality—*Mann and Brigham 352* (BISH, G, NY, US) (fragments: st. lv. bd. fl.).

This variety, which was considered by many botanists to be the same as Gray's var. *glabrata* of Puna, Hawaii, is now separated from that variety and named for its occurrence on the island of Lanai.

11. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata*, var. nov.

Foliolis oblonge obovatis vel oblongis vel oblonge ovatis, basi cuneatis; vexillo ovato, apice retuso, basi obtuso.

Leaflets oblong-obovate to oblong to oblong-ovate, the base cuneate; rachis-petiole up to 17 cm. long; calyx tube 8-15 mm. broad, 4-12 mm. high; the standard ovate, the apex retuse, the base obtuse, 13.5-23 mm. broad, 13-18 mm. long; seeds golden brown.

12. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *ovata*, subvar. nov.

Rhachide cum petiolo longitudine quam 12 cm. breviori; foliolis 3-23 mm. latis, 10-50 mm. longis; petalis alarum oblongis vel ellip-

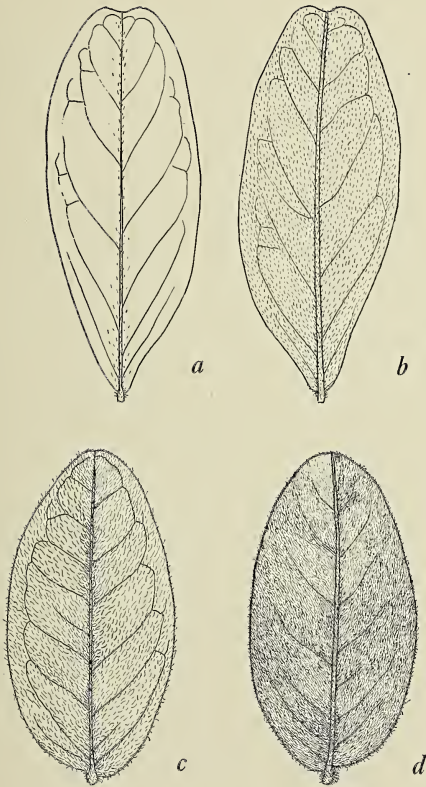


FIG. 9. Leaflet of var. *lanaiensis*, Rock 8012: a, upper surface,  $\times 2$ ; b, lower surface,  $\times 2$ . Leaflet of f. *ovata*, Chock et al. 592: c, upper surface,  $\times 1.5$ ; d, lower surface,  $\times 1.5$ .



ticis; petalis carinae oblonge ovatis vel ellipticis.

Rachis-petiole length up to 12 cm.; leaflets 3–23 mm. broad, 10–50 mm. long; the petals of the wing oblong or elliptic, the apex obtuse, the margin sometimes irregularly indented toward the base; the petals of the keel oblong-ovate to elliptic, the margin sometimes irregularly indented toward the base.

13. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *ovata* f. *ovata*, forma  
nov.

Figs. 7, 9c, d

Petalis alarum ellipticis, apice obtusis, basi truncatis; petalis carinae ovatis, apice obtusis, basi truncatis.

The standard 15–18 mm. broad, 14–16 mm. long; the petals of the wing elliptic, the base truncate, margin entire, 6–9.5 mm. broad, 14–18 mm. long; the petals of the keel oblong-ovate, the apex obtuse, the base truncate, the margin entire.

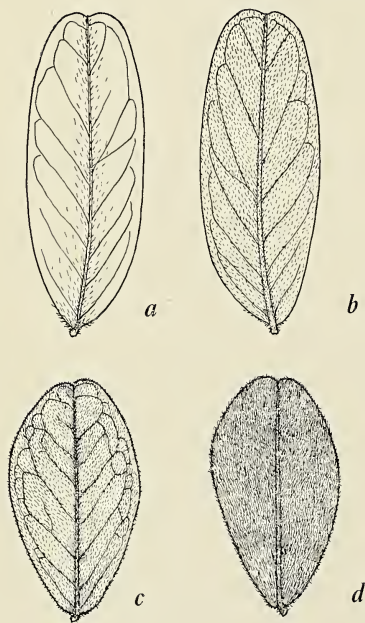


FIG. 10. Leaflet of f. *puuwaawaensis*, Chock et al. 799: a, upper surface,  $\times 2$ ; b, lower surface,  $\times 2$ . Leaflet of f. *maunakeaensis*, Chock et al. 578: c, upper surface,  $\times 1$ ; d, lower surface,  $\times 1$ .

TYPE: **Hawaii**, Mauna Kea, southeast slope, 6.9 miles northeast of Humuula, Mauna Kea contour road, 7,000 feet, Aug. 31, 1952, Chock et al. 592 (BISH) (st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: **Hawaii**, Mauna Kea, east slope, Mauna Kea contour road, near Laumaia, 6,700–9,000 feet, Aug. 31, 1952 —Chock et al. 594 (st. lv. bd. fr.); Chock et al. 611 (st. lv. bd. fl. fr.); Chock et al. 615 (st. lv. fr.); Chock et al. 618 (st. lv. fr.); Chock et al. 620 (st. lv. bd. fl. fr.); Chock et al. 621 (st. lv. bd. fr.); Aug. 18, 1935, Neal and Hartt 866 (st. lv. bd. fl.). Mauna Loa, north slope, Hilo-Kona road, 8,000 feet, Sept. 3, 1952—Chock et al. 662 (st. lv. fr.); Chock et al. 664 (st. lv. fr.); Chock et al. 667 (st. lv. fr.); Chock et al. 670 (st. lv. bd. fl. fr.).

This form is named for the ovate standard petal.

14. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *ovata* f. *puuwaawaensis*, forma nov.

Figs. 3c, 7, 10a, b

Foliolis subtus glabratiss; petalis alarum carinaeque irregulariter indentatis, basi modice in latere uno hastatis, altero truncatis.

Leaflets glabrate, 5–14 mm. broad, 12–25 mm. long; calyx tube 8 mm. broad, 6–9 mm. high; the petals of the wing oblong, the base truncate on one side and moderately hastate on the other side, the margin sometimes irregularly indented toward the base, 4–5 mm. broad, 13–15 mm. long; the petals of the keel oblong-elliptic, the margin irregularly indented toward the base, 7–8 mm. broad, 15 mm. long; pods 3.8–12 cm. long, 9–13 mm. wide; seeds golden brown.

TYPE: **Hawaii**, North Kona District, Mamelahoa highway, 4.1 miles northeast of Puu Waawaa Ranch road, 2,300 feet, Sept. 10, 1952, Chock et al. 799 (BISH) (st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: **Hawaii**, Puu Waawaa Ranch, 1,800 to 2,300 feet, Sept. 8, 1952 —Chock et al. 783 (st. lv. bd. fl.); Chock et al.

784 (st. lv. fr.); *Chock et al.* 785 (st. lv. bd. fr.); *Chock et al.* 788 (st. lv. bd. fr.); Sept. 10, 1952, *Chock et al.* 798 (st. lv. bd. fl. fr.); Sept. 7, 1949, *Degener* 20,109 (F) (st. lv. bd. fl. fr.); Huehue, Feb. 11, 1952, *Degener* 21,818 (F) (st. lv. bd. fl. fr.).

This form is named for its occurrence in the Puu Waawaa region on the island of Hawaii.

15. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *ovata* f. *maunakea-*  
*ensis*, forma nov.

Figs. 2a, 7, 10c, d

Foliolis subtus dense pubescentibus; petalis alarum integris, basi truncatis; petalis carinae irregulariter indentatis, basi truncatis.

Leaflets abundantly pubescent on the lower surface, 5–15 mm. broad, 10–34 mm. long; the petals of the wing elliptic, the base truncate, the margin entire, 7–7.5 mm. broad, 14.5–17.5 mm. long; the petals of the keel elliptic, the base truncate, the margin irregularly indented toward the base, 8–8.5 mm. broad, 16–19 mm. long; seeds golden brown.

TYPE: Hawaii, Mauna Kea, south slope, 3.1 miles north of Humuula, Humuula-Hale Pohaku road, Aug. 30, 1952, *Chock et al.* 578 (BISH) (st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: Hawaii, Mauna Kea, south slope, Humuula-Hale Pohaku road, 8,000–10,000 feet, Aug. 30, 1952—*Chock et al.* 580 (st. lv. bd. fl.); near timberline, *Chock et al.* 577 (wood, st. lv. bd. fl. fr.); Sept. 2, 1949, *Degener & Murashige* 19,997 (F) (st. lv. bd. fl. fr.); Sept., 1949, *Degener* (F) (st. lv. fl.); Aug. 18, 1949, *Degener* 20,236 (F) (st. lv. bd. fl. fr.).

This form is named for its occurrence on the slopes of Mauna Kea on the island of Hawaii.

16. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *mauiensis*, subvar.  
nov.

Rhachide cum petiolo minus quam 17 cm. longo; foliolis 5–12 mm. latis, 13–32 mm.

longis; petalis alarum carinaeque oblonge ellipticis.

Leaflets 5–12 mm. broad, 13–32 mm. long; rachis-petiolo up to 17 cm. long; the standard ovate; the petals of the wing oblong-elliptic, the base cuneate on one side and hastate on the other side; the petals of the keel oblong-elliptic, the margin usually irregularly indented toward the base; seeds golden brown.

17. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *mauiensis* f. *maui-*  
*ensis*, forma nov.

Figs. 3a, 7, 11a, b

Vexillo ovato, 23 mm. lato, 18 mm. longo; petalis carinae basi oblique truncatis, apice acutis.

Rachis-petiolo up to 9 cm. long; the petals of the wing 8.5 mm. broad, 18.5 mm. long, the apex obtuse; the petals of the keel 10

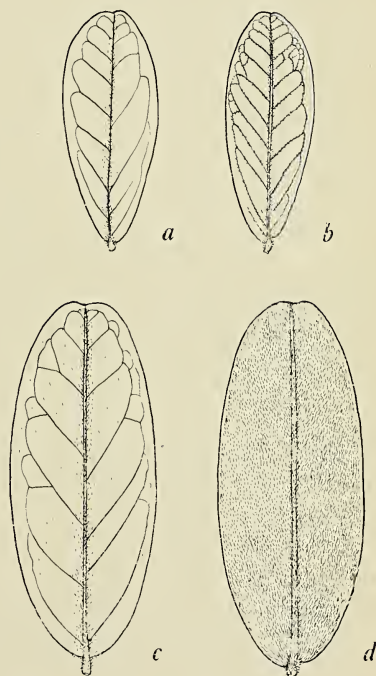


FIG. 11. Leaflet of f. *mauiensis*, Chock et al. 283: a, upper surface,  $\times 1$ ; b, lower surface,  $\times 1$ . Leaflet of f. *lualabaensis*, Forbes 1986M: c, upper surface,  $\times 2$ ; d, lower surface,  $\times 2$ .



mm. broad, 20 mm. long, the apex acute, the base truncate-oblique.

TYPE: **Maui**, Haleakala, north-west-west slope, 0.8 miles from 8,000 feet level (road marker), Haleakala road, 8,450 feet altitude, Dec. 24, 1951, *Chock et al.* 283 (BISH) (st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: **Maui**, Haleakala—between Olinda and Haleakala summit, June 15, 1927, *Degener and Wiebke* 2279 (NY, US) (st. lv. fr.); 1,666 M., Feb., 26, 1902, *J. G. Smith* (US) (st. fl.); 8,000 ft., April 1, 1947, *Alexander & Kellogg* 5285 (US) (st. lv. bd. fl.).

This form is named for its occurrence on Maui.

18. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *mauiensis* f. *lualailuensis*, forma nov.

Figs. 7, 11c, d

Vexillo ovato, 15 mm. lato, 13 mm. longo; petalis carinae basi truncatis apice obtusis.

Rachis-petiole up to 11 cm. long; the standard 15 mm. broad, 13 mm. long; the petals of the wing 7 mm. broad, 15 mm. long, the apex obtuse; the petals of the keel 8 mm. broad, 15 mm. long, the apex obtuse, the base truncate.

TYPE: **Maui**, cone of south side of Haleakala, cone near Lualailua Hills, Kohekanawa [?], Mar. 17, 1920, *Forbes* 1986M (BISH) (st. lv. bd. fl.).

This form is named for its occurrence near the Lualailua Hills, Maui.

19. *Sophora chrysophylla* ssp. *glabrata*  
var. *ovata* subvar. *mauiensis* f. *olindaensis*, forma nov.

Figs. 2b, 7, 12

Rhachide cum petiolo minus quam 17 cm. longo; petalis carinae oblonge ellipticis, apice obtusis, basi obtusis vel oblique truncatis.

Rachis-petiole up to 17 cm. long; the petals of the wing 8 mm. broad, 20 mm. long, the apex acute, the base truncate; the petals of the keel 10 mm. broad, 22 mm. wide, the

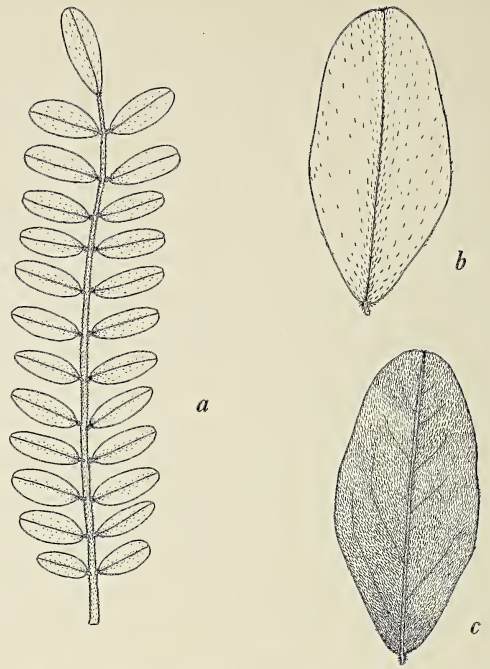


FIG. 12. *S. olindaensis*, Chock et al. 286: a, leaf, upper surface,  $\times 0.5$ ; b, leaflet, upper surface,  $\times 2$ ; c, leaflet, lower surface,  $\times 2$ .

apex obtuse, the base obtuse to truncate-oblique.

TYPE: **Maui**, Makawao, Olinda Pipe Line road, 4,600 feet, in wet gulch, tree 10 meters high with few leaves and large number of flowers, Dec. 25, 1951, *Chock et al.* 286 (BISH) (st. lv. bd. fl.).

SPECIMENS EXAMINED: Same locality, Dec. 25, 1951, *Chock et al.* 311 (st. lv. bd. fl.); same locality, June 27, 1927, *Degener* (NY) (st. lv. bd.).

This form grows in an area where the rainfall is over 200 inches a year, and is named for its occurrence in the Olinda region, Maui.

20. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* (*Degener and Sherff*), comb. nov.

*Sophora grisea* *Degener and Sherff*, in *Sherff*, Bot. Leaflets, 5: 24–25, 1951.

Leaflets broadly elliptic to oblong-ovate to oblong to oblong-ovate, abundantly pube-

scent, 3–22 mm. broad, 7–40 mm. long; petiolule 0.5–1.5 mm. long; rachis-petiole up to 16.5 cm. long; pedicels 5–25 mm. long; calyx tube 5–10 mm. broad, 6–11 mm. high; the standard ovate to oblong-ovate, the apex and base obtuse, 10.5–17 mm. broad, 12–17 mm. long; the petals of the wing 4.5–8 mm. broad, 13–19 mm. long, the base usually truncate; the petals of the keel 5–12 mm. broad, 14–20 mm. long, the base usually truncate; pods 2–14.5 cm. long, 7–15 mm. wide; seeds gray-black to golden brown.

21. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* subvar. *grisea* (Degener and Sherff), comb. nov.

Figs. 8, 13a, b

*Sophora grisea* Degener and Sherff, in Sherff, Bot. Leaflets 5: 24–25, 1951.

Leaflets usually broadly elliptic, 6–22 mm. broad, 14–40 mm. long; rachis-petiole up to 11 cm. long; calyx tube 9.5 mm. broad, 7 mm. high; the standard oblong-ovate, 10.5–12 mm. broad, 15–17 mm. long; the petals of the wing oblong-lanceolate, 4–5 mm. broad, 14 mm. long; the petals of the keel oblong to

oblong-ovate, 5–8 mm. broad, 15–17 mm. long; pods 7 mm. wide, including the wings, which are 1–15 mm.; seeds gray-black.

TYPE: Oahu, Waianae Mts., DuPont trail, Oct. 23, 1949, *Degener and Greenwell* (F, type; BISH, fragment of type) (st. lv. fr.).

SPECIMENS EXAMINED: Oahu—Waianae Mts., Makaha valley, Feb. 12–19, 1909, *Forbes* (st. lv. fl.); *Remy*, ex. herb. A. Gray (NY) (st. lv. bd. fl.); Dec. 4, 1951, *Degener* (F) (st. lv.); DuPont trail, 2,500 ft., Sept. 9, 1950, *Hatheway, et al.*, 349 (F) (st. lv. fl.).

This taxon was named by Degener and Sherff in allusion to the seed color.

22. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* subvar. *obtusa*, subvar. nov.

Foliolis oblongis vel oblonge obovatis, basi cuneatis; vexillo ovato, apice obtuso.

Leaflets oblong-obovate to oblong to oblong-ovate, the base cuneate; the standard ovate, the apex obtuse, 12–15 mm. broad, 12–17 mm. long; the petals of the wing with the apex obtuse; the petals of the keel 6–8 mm. broad, 14–17.5 mm. long; seeds golden brown.

23. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* subvar. *obtusa* f. *obtusa*, forma nov.

Figs. 2e, 3e, 8, 13c, d

Petalis alarum ellipticis, apice obtusis, basi modice sagittatis; petalis carinae oblongis, apice obtusis, basi obtusis in latere uno, in altero modice sagittatis.

Leaflets oblong-obovate, 5–15 mm. broad, 10–34 mm. long; rachis-petiole up to 13 cm. long; the petals of the wing elliptic, the apex obtuse, the base moderately sagittate, 7.5 mm. wide, 13 mm. long; the petals of the keel oblong, the apex obtuse, the base obtuse on one side and moderately sagittate on the other side, 6 mm. broad, 14 mm. long.

TYPE: Hawaii, Mauna Kea—Mauna Loa Saddle, Waikii, 10.4 miles west of Pohakuloa, 5,500 feet, Aug. 30, 1952, *Chock, et al.*, 584 (BISH) (st. lv. bd. fl. fr.).

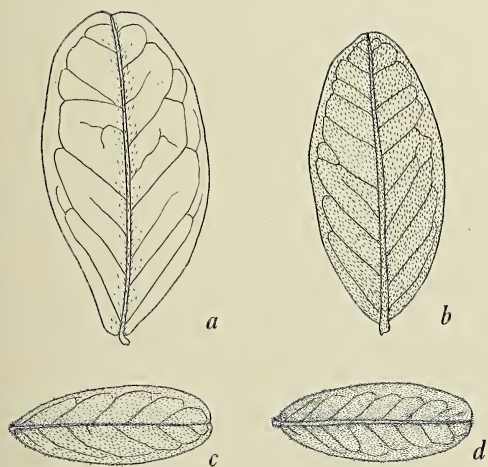


FIG. 13. Leaflet of subvar. *grisea*: a, upper surface,  $\times 1$ , Degener and Greenwell (October 23, 1949); b, lower surface,  $\times 1$ , Forbes (February 12–19, 1909). Leaflet of f. *obtusa*, Chock et al. 584: c, upper surface,  $\times 1$ ; d, lower surface,  $\times 1$ .



SPECIMENS EXAMINED: **Hawaii**, Mauna Kea—Mauna Loa Saddle—Waikii, Aug. 30, 1952, *Chock, et al.*, 582 (st. lv. bd. fr.); same locality, *Chock, et al.*, 583 (st. lv. bd. fr.); Pohakuloa, Bd. of Agr. & For. camp, 6,000 feet, Sept. 1, 1952, *Chock, et al.*, 625 (st. lv. fr.).

This form is named for the obtuse apex of the standard petal.

24. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* subvar. *obtusa* f. *maunaloa-*  
*ensis*, forma nov.

Figs. 8, 14*a, b*

Petalis alarum oblongis, apice obtusis, basi

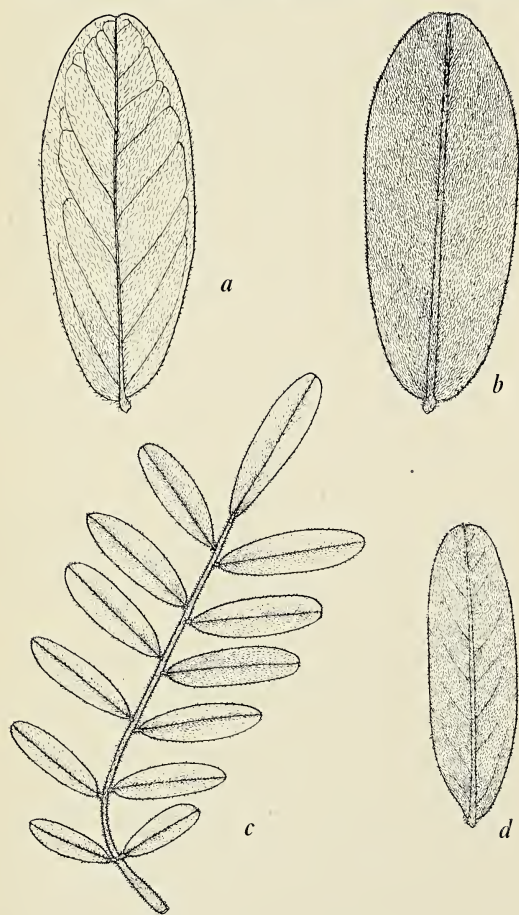


FIG. 14. Leaflet of f. *maunaloaensis*, Chock et al. 726: *a*, upper surface,  $\times 1$ ; *b*, lower surface,  $\times 1$ . Leaf and leaflet of f. *parva*, Chock et al. 782: *c*, leaf, upper surface,  $\times 1$ ; *d*, leaflet, lower surface,  $\times 2$ .

truncatis; petalis carinae oblonge ellipticis, apice acutis, basi subsagittatis.

Leaflets oblong-obovate, 5–16 mm. broad, 10–41 mm. long; rachis-petiole up to 13 cm. long; the petals of the wing oblong, 7–8 mm. broad, 19 mm. long; the petals of the keel oblong-elliptic, the apex acute, the base subsagittate, 8 mm. broad, 16 mm. long; seeds golden brown.

TYPE: **Hawaii**, Hawaii Natl. Park, Feb., 1952, *Hubbard* (BISH) (st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: **Hawaii**, Mauna Loa, southeast slopes, Hawaii Natl. Park, Mauna Loa—Kilauea section road, Sept. 5, 1952—6,700 feet, *Chock, et al.*, 726 (st. lv. fr.); same locality, *Chock, et al.*, 727 (st. lv. fr.); same locality, *Chock, et al.*, 728 (st. lv. bd. fr.); 4,400 feet, *Chock, et al.*, 730 (st. lv. bd. fr.); same locality, *Chock, et al.*, 733 (st. lv. bd. fr.).

**Hawaii**, Hawaii Natl. Park, Mauna Loa—Kilauea section—in kipuka 8.5 miles along Kau road from Volcano House, July 22, 1926, *Degener* 9848 (NY) (st. lv. fl. fr.); Sept., 1908, *Forbes, et al.*, (BISH, NY) (st. lv. fr.); lava "oasis" beyond Bird Park, Dec. 26, 1922, *Degener* (NY) (st. lv. fr.); 7 miles west of Volcano House along Kau road, July 21, 1926, *Degener* 9844 (NY) (st. lv. fr.); Kilauea (drawn for *Plants of Hawaii Natl. Park*, plate 47), Aug., 1929, *Degener* (NY) (st. lv. bd. fr.); on trail to rest house (Mauna Loa), 7,000 ft., Sept. 13, 1916, *A. S. Hitchcock* 14,634 (US) (st. lv. bd. fl.); east of Kilauea-iki, July 17, 1926, *Degener* 9845 (US) (st. lv. bd.); Bird Park, 4,000 ft., Dec. 22, 1931, *St. John, et al.*, 11,261 (BISH, US) (st. lv. bd. fl.).

This form is named for its occurrence on the eastern slopes of Mauna Loa in Hawaii National Park.

25. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* subvar. *obtusa* f. *parva*,  
forma nov.

Figs. 8, 14*c, d*

Foliolis glabratis; petalis alarum oblongis, apice obtusis, basi in latere uno cuneatis, in

altero modice hastatis; petalis carinae oblongis, apice acutis, basi oblique truncatis.

Leaflets glabrate, 3–11 mm. broad, 7–20 mm. long; rachis-petiole length up to 7 cm.; the petals of the wing oblong, the apex obtuse, the base truncate or cuneate on one side and moderately hastate on the other side, 4.5–5 mm. broad, 14 mm. long; the petals of the keel oblong, the apex acute, the base truncate-oblique, 6.5–7 mm. broad, 16.5–17.5 mm. long; pods 2–4 cm. long, the wings 1.5–2.5 mm. wide, 1–4 seeded, usually 2 seeded.

TYPE: **Hawaii**, North Kona District, Puu Waawaa Ranch, junction of Mamalahoa highway and Puu Waawaa ranch road, 2,300 ft., Sept. 8, 1952, *Chock, et al.*, 782 (BISH) (st. lv. bd. fl.).

SPECIMENS EXAMINED: **Hawaii**, Puu Waawaa Ranch—2,300 ft., Sept. 8, 1952, *Chock, et al.*, 775 (st. lv. bd. fr.); 3 miles west of Puu Waawaa, 3,000 ft., June 21–23, 1948, *Wilbur and Webster* 1887 (st. lv. fl.).

This form is named in allusion to its small size in habit, the narrow wings of the pods, and the small leaflets.

26. *Sophora chrysophylla* ssp. *glabrata*  
var. *grisea* subvar. *ovatifoliolata*, sub-  
var. nov.

Figs. 8, 15*a, b*

Foliolis oblonge ovatis.

Leaflets ovate-oblong, the few larger leaflets being oblong to obovate-oblong, 6–17 mm. broad, 15–38 mm. long; calyx tube 9.5 mm. broad, 11 mm. high; the standard ovate, 17 mm. broad, 17 mm. long; the petals of the wing ovate-oblong, 8 mm. broad, 19 mm. long; the petals of the keel elliptic, the apex obtuse, 12 mm. broad, 20 mm. long; the wings of the pods under 2 mm. wide; seeds orange-brown.

TYPE: **Kauai**, Na Pali-Kona Forest Reserve, Kokee Terr. Park, 4,000 feet, near Kalalau Lookout, in rain forest, specimen from 2–3 trees (7 m. x 5 cm.), Dec. 24, 1952, *St. John, et al.*, 24,879 (BISH) (st. lv. bd. fl. fr.).

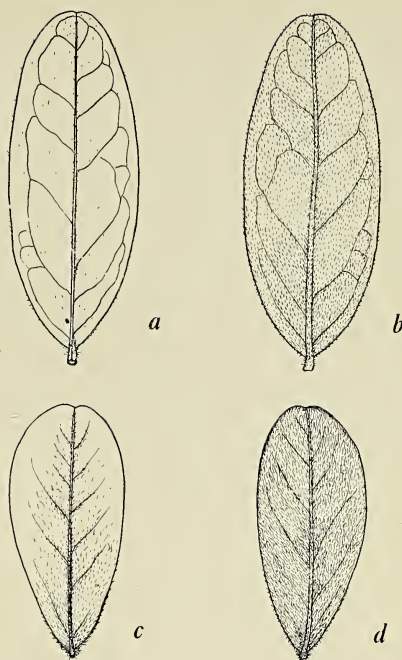


FIG. 15. Leaflet of subvar. *ovatifoliolata*, St. John et al. 24,879: *a*, upper surface,  $\times 1.5$ ; *b*, lower surface,  $\times 1.5$ . Leaflet of var. *circularis*, Chock et al. 612: *c*, upper surface,  $\times 1$ ; *d*, lower surface,  $\times 1$ .

SPECIMENS EXAMINED: **Kauai**, Kokee Terr. Park—same locality as type, Nov., 1951, *Souza* (st. lv. bd. fr.); same locality, July 4, 1926, *Degener* 9847 (NY) (st. lv.); same locality, *Degener and Greenwell*, 21,513 (F) (lv. fl. bd.); Kaunuohua ridge, northeast of Pohakuwaawaa, Jan. 12, 1952, *Degener and Greenwell* 21,745 (F) (st. lv. bd. fl.); Kapiwai trail, Jan. 11, 1952, *Degener and Greenwell* 21,742 (F) (st. lv. bd. fl.); Nualolo trail, 2,000–3,750 feet, Dec. 28, 1930, *St. John, et al.*, 10,810 (st. lv. bd. fl.); Waimea Drainage Basin, west side, Nualolo trail, July 3 to Aug. 18, 1917, *Forbes* 965K (st. lv.); road to Halemanu hill, 3,700 feet, Sept. 7, 1953, *Chock* 1194 (st. lv. fr.); same locality, *Chock* 1196 (st. lv.).

A large number of seedlings were observed near Halemanu hill, with several scrubby trees 2 meters high. This subvariety is named in allusion to the ovate leaflets.



27. *Sophora chrysophylla* ssp. *circularis*,  
ssp. nov.

Figs. 1, 19

Vexillo circulari.

Shrub to tree, 4–5 meters high; leaflets oblong-obovate, 6–14 mm. broad, 13–37 mm. long, abundantly pubescent to glabrate; petiolule 1–1.5 mm.; rachis-petiole up to 12 cm. long; pedicels 6–13 mm. long; the standard circular, the apex retuse, the base obtuse, the breadth and length the same, 13–18 mm.; the petals of the wing with the apex obtuse, the base hastate on one side and truncate on the other side; pods 4–11 cm. long, 7–17 mm. wide, 1–7 seeded; seeds orange-brown or golden brown.

KEY TO SUBSPECIES *circularis*

- A. Rachis-petiole maximum length 12 cm.; pubescence on the lower surface of the leaflets abundant; wing petals elliptic. . . . . 28. var. *circularis*  
A. Rachis-petiole maximum length 7 cm.; lower surface of leaflets glabrate; wing petals oblong-lanceolate. . . . . 29. var. *kauensis*

28. *Sophora chrysophylla* ssp. *circularis*  
var. *circularis*, var. nov.

Figs. 2*d*, 3*d*, 15*c*, *d*, 19

Rhachide cum petiolo minus quam 12 cm. longo; foliolis subtus dense pubescentibus; petalis alarum ellipticis.

The lower surface of the leaflets abundant strigose-pubescent; rachis-petiole up to 12 cm. long; calyx tube 12 mm. broad, 10 mm. high; the petals of the keel elliptic, the apex obtuse, the base cuneate on one side and truncate on the other side, the margin irregularly indented toward the base, 9 mm. broad, 19 mm. long; pods 3 seeded, the wings 3 mm. wide; seeds golden brown, 5 mm. wide, 7–8 mm. long, 4 mm. thick.

TYPE: **Hawaii**, Mauna Kea, east slope, 15.9 miles northeast of Humuula, Mauna Kea

contour road, 6,700 feet, Aug. 31, 1952, Chock, et al., 612 (BISH) (st. lv. bd. fl. fr.).

This variety is named for the circular petal.

29. *Sophora chrysophylla* ssp. *circularis*  
var. *kauensis*, var. nov.

Figs. 1*c*, 2*c*, 3*b*, 16*a*, *b*, 19

Rhachide cum petiolo minus quam 7 cm. longo; foliolis subtus glabratibus; petalis alarum oblonge lanceolatis.

The lower surface of the leaflets glabrate; rachis-petiole up to 7 cm. long; calyx tube 8 mm. broad, 8 mm. high; the petals of the wing oblong-lanceolate, 5.5 mm. broad, 14 mm. long; the petals of the keel oblong-elliptic, the apex acute, the base cuneate on one side and hastate on the other side, 8.5 mm. broad, 17 mm. long; pods 1–7 seeded;

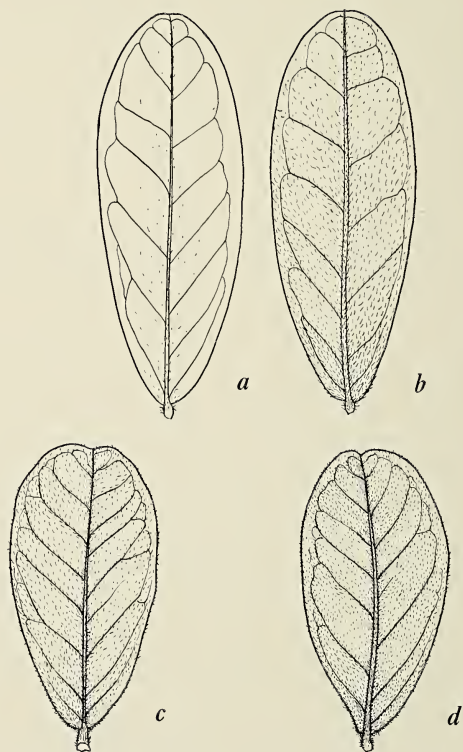


FIG. 16. Leaflet of var. *kauensis*, Chock et al. 749: *a*, upper surface,  $\times 2$ ; *b*, lower surface,  $\times 2$ . Unifoliolate leaf of var. *unifoliata*, Rock 13,011: *c*, upper surface,  $\times 1$ ; *d*, lower surface,  $\times 1$ .

seeds orange-brown, 3–4 mm. wide, 5 mm. long, 2.5–3.5 mm. thick.

TYPE: **Hawaii**, Kau District, Mamalahoa highway, 4.5 miles west of Kahuku Ranch entrance, 1,900 feet, Sept. 6, 1952, *Chock, et al.*, 749 (BISH) (wood, st. lv. bd. fl. fr.).

SPECIMENS EXAMINED: **Hawaii**, near 1907 lava flow, Feb. 14, 1952, *Degener* 21,820 (F) (st. lv. bd. fl. fr.).

This variety is named for its occurrence in the Kau District on the island of Hawaii.

30. *Sophora chrysophylla* ssp. *unifoliata* (Rock), comb. nov.

Figs. 1*b*, 19

*Sophora chrysophylla* var. *unifoliata* Rock, Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry, Bot. Bul. 5: 44, 1919.

*Edwardsia unifoliata* (Rock) Degener, Flora Hawaiiensis, family 169c, 1932.

*Sophora unifoliata* (Rock) Degener and Sherff, in Sherff, Bot. Leaflets 5: 24, 1951.

Shrub to tree, 3.5–8 meters high, leaves alternate, unifoliolate to pinnate; leaflets oblong-obovate, 6–19 mm. broad, 12–49 mm. long; petiolule 1 mm.; rachis-petiole (of pinnate leaves) up to 8.5 cm. long; pedicels 5–18 mm.; calyx tube 7–10 mm. broad, 4–8 mm. high; the standard elliptic, 10–16 mm. broad, 13–20 mm. long; the petals of the wing oblong-lanceolate, the apex obtuse, the base hastate, 3–5 mm. broad, 12.5–21 mm. long; the petals of the keel oblong to oblong-lanceolate, 3–6.5 mm. broad, 8–25 mm. long; no fruits on specimens.

KEY TO SUBSPECIES *unifoliata*

- A. Leaves typically unifoliolate to trifoliolate, petiole 2 mm.; margin of keel sometimes irregularly indented. . . 31. var. *unifoliata*
- A. Leaves typically pinnate (5–21 leaflets), but sometimes unifoliolate to trifoliolate, petiole over 2 mm.; margin of keel always entire. . . . . B

B. Leaves always pinnate (5–21 leaflets), never unifoliolate, bifoliolate, or trifoliolate; leaflets 6–9 mm. broad, 12–26 mm. long; keel oblong-lanceolate, apex acute. . . . . 33. var. *kanaioensis*

B. Leaves pinnate (5–11 leaflets), but sometimes unifoliolate, bifoliolate or trifoliolate; leaflets 6–14 mm. broad, 18–49 mm. long; keel oblong, apex obtuse. . . . . 32. var. *elliptica*

31. *Sophora chrysophylla* ssp. *unifoliata* var. *unifoliata* Rock, Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry, Bot. Bul. 5: 44, 1919.

Figs. 16*c*, 19

*Edwardsia unifoliata* (Rock) Degener, Flora Hawaiiensis, family 169c, 1932.

*Sophora unifoliata* (Rock) Degener and Sherff, in Sherff, Bot. Leaflets 5: 24, 1951.

Leaves alternate, usually unifoliolate, but sometimes bifoliolate or trifoliolate; petiole up to 2 mm.; the petals of the keel oblong, the apex obtuse, the base cuneate on one side and truncate on the other side, the margin irregularly indented toward the base.

TYPE: **Hawaii**, Puu Waawaa, 2,000 feet, Aug., 1917, *Rock* 13,011 (BISH) (st. lv. bd. fl.).

SPECIMENS EXAMINED: **Hawaii**, Puu Waawaa—1913, *Young* 12,648 (st. lv. bd.); 900 m., wood sample no. phloem 180, Dec. 1, 1926, *MacDaniels* (st. lv. fl.); *Meebold* (*Degener's*) 10,138 (st. lv. bd. fl.).

Meebold's specimen shows a double pistil on all of the flowers, while Rock's type specimen does not show such an abnormality. The one flower on MacDaniels' specimen showed a development toward a double pistil, since there was a longitudinal depression.

Fruits were found in an envelope on the sheet of Young's specimen, which probably do not belong to this particular collection, since Rock (1919: 44) states, "no pods seen." The envelope on this sheet appears to be of recent origin, and later collectors failed to find any pods.



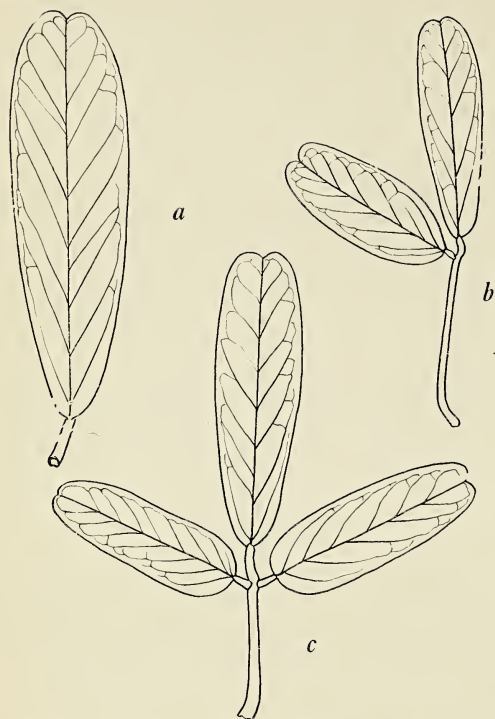


FIG. 17. Leaves of var. *elliptica*, Degener et al. 19,327: *a*, unifoliate leaf,  $\times 1$ ; *b*, bifoliate leaf,  $\times 1$ ; *c*, trifoliate leaf,  $\times 1$ .

32. *Sophora chrysophylla* ssp. *unifoliata*  
var. *elliptica*, var. nov.

Figs. 1*b*, 17, 18*a*, *b*, 19

Foliis unifoliolatis vel pinnatis; petalis carinae oblongis, apice obtusis.

Leaves pinnate, but sometimes unifoliate, bifoliate or trifoliate, 6–14 mm. broad, 18–49 mm. long; the standard with the apex retuse, the base cuneate, 16 mm. broad, 20 mm. long; the petals of the wing 5 mm. broad, 21 mm. long; the petals of the keel oblong, the apex obtuse, the base cuneate on one side and hastate on the other side.

TYPE: Maui, Hokukano, Dec. 27, 1948, Degener, Bertram, Clay 19,327 (type, BISH; isotype, F) (st. lv. bd. fl.).

This variety has pinnate, unifoliate, bifoliate, and trifoliate leaves, and represents a transitional stage between var. *uni-*

*foliata* and the more common mamane. It is named for the elliptic standard petal.

33. *Sophora chrysophylla* ssp. *unifoliata*  
var. *kanaioensis*, var. nov.

Figs. 18*c*, *d*, 19

Foliis pinnatis; vexillo oblonge elliptico; petalis carinae oblonge lanceolatis, apice acutis.

Leaves alternate, always pinnate; leaflets oblong to oblong-obovate, 6–9 mm. broad, 16–26 mm. long; rachis-petiole up to 5 cm. long; calyx tube prominently nerved; corolla orange (according to Forbes' label); the

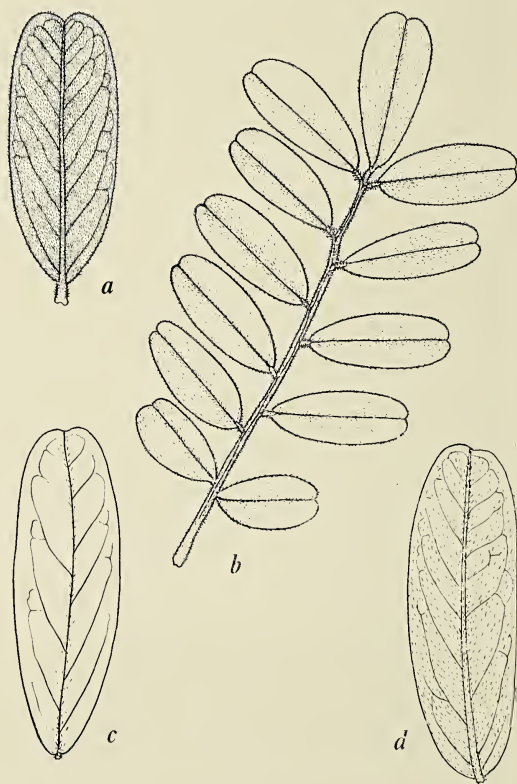


FIG. 18. Pinnate leaf of var. *elliptica*, Degener et al. 19,327: *a*, leaflet, lower surface,  $\times 2$ ; *b*, pinnate leaf, upper surface,  $\times 1$ . Leaflet of var. *kanaioensis*, Forbes. 1807M: *c*, upper surface,  $\times 2$ ; *d*, lower surface,  $\times 2$ .

standard oblong-elliptic, the apex retuse, the base obtuse, 12 mm. broad, 18 mm. long; the petals of the wing 3 mm. broad, 20 mm. long, the base 4 mm.; the petals of the keel oblong-lanceolate, the apex acute, the base hastate.

TYPE: Maui, Kanaio, Mar. 2, 1920, *Forbes* 1807M (BISH) (st. lv. bd. fl.).

SPECIMENS EXAMINED: Maui, Kanaio, Feb. 27, 1952, *Degener* 21,976 (F) (st. lv. bd. fl. fr.).

This form is named in allusion to its occurrence near Kanaio on the island of Maui.

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HAWAIIAN ISLANDS ASSEMBLED



FIG. 19. Map of distribution of *Sophora chrysophylla*: ssp. *circularis*—open circle represents var. *circularis*, solid circle var. *kauensis*; ssp. *unifoliata*—open erect triangle represents var. *unifoliata*, solid erect triangle var. *elliptica*, open inverted triangle var. *kanaioensis*.



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## A Revision of the Surgeon Fish Genus *Acanthurus*<sup>1</sup>

JOHN E. RANDALL

THIS IS THE FOURTH in a series of papers dealing with the surgeon fishes (family Acanthuridae). An analysis of the genera and revisions of *Zebrasoma*, *Paracanthurus*, and *Ctenochaetus* have been published (Randall, 1955a, b, c). *Acanthurus*, with 32 species (one of which is described as new), is treated in the present paper, the first to consider all of the species of this circumtropical genus since the review by Günther in 1861.

The work has been based primarily on the collections of surgeon fishes in the following institutions: United States National Museum, Stanford Natural History Museum, California Academy of Sciences, Museum of Comparative Zoology at Harvard College, Bernice P. Bishop Museum, Academy of Natural Sciences of Philadelphia, University of Hawaii, University of Miami, University of California at Los Angeles, and the Pacific Oceanic Fishery Investigations, Honolulu.

I acknowledge with gratitude the assistance and guidance of William A. Gosline of the University of Hawaii and Leonard P. Schultz, Ernest A. Lachner, Robert H. Kanazawa, and Frederick M. Bayer of the United States National Museum.

Special thanks are due Boyd W. Walker of the University of California at Los Angeles, George S. Myers and Robert R. Harry of Stanford University, Joseph E. King of the Pacific Oceanic Fishery Investigations, and J. L. B. Smith of Rhodes University College, South Africa for information and loan of specimens.

I am grateful to L. Bertin of the Museum National d'Histoire Naturelle at Paris, W. Klausewitz of the Senckenberg Museum at Frankfurt, N. B. Marshall and especially Alwyne C. Wheeler of the British Museum of Natural History who have been most cooperative in supplying information on type specimens.

I am most appreciative of the assistance and advice of the research laboratories of the Eastman Kodak Company on the colored plates and for the printing of Plate 2.

E. J. Brill of Leiden, Netherlands, have kindly permitted the use of the figure of *Acanthurus leucosternon* published as Figure 26 of Volume IX of *Fishes of the Indo-Australian Archipelago* by L. F. deBeaufort and W. M. Chapman.

Most of the species of *Acanthurus* are wide-ranging and have been described many times under different names. A total of 110 Recent specific names, discounting misspellings, have been proposed for *Acanthurus* and its synonyms, and seven names from other surgeon

<sup>1</sup> A portion of a thesis submitted to the Department of Zoology, University of Hawaii, in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Contribution No. 75, Hawaii Marine Laboratory in cooperation with the Department of Zoology and Entomology, University of Hawaii. Manuscript received April 20, 1955.



fish genera have been applied to species of the genus.

In the preparation of the synonymy for each species, mere listings or names with insufficient descriptive data have been omitted generally unless I have seen the specimens reported. References in the synonymy are given with no locality when an author did not cite the locality or when he based his record on the work of a previous author. Misidentifications are indicated by a period immediately following the specific name.

The original descriptions of a few species for which there are no known types are so fragmentary (or in cases probably erroneous) that it would be pure guess work to allocate the names to known forms. In this category are the following: *Acanthurus Militaris* Shaw, *Acanthurus Umbratus* Shaw, *Acanthurus Meleagris* Shaw, *Acanthurus fuliginosus* Lesson, *Acanthurus fraterculus* Cuvier and Valenciennes, and *Acanthurus lineolatus* Cuvier and Valenciennes.

The only species of *Acanthurus* described by Shaw (1803) which has been recognized is *A. achilles*. I have never seen other Shaw names used, and the descriptions are much too brief to permit identifications. A. C. Wheeler of the British Museum answered my query about types by writing, "I have searched everywhere for Shaw's types, and I am quite certain that they are now not in existence, be they in spirit, stuffed, or skins."

*Acanthurus fuliginosus* was figured by Lesson (1830: pl. 27, fig. 2) as a uniformly brown fish with a broad bright blue line under the chin. In life there were fine, transverse, reddish lines on the body. I know of no species with such coloration. Certainly the use of the name by Fowler, Schultz, and others for *Acanthurus xanthopterus* Cuvier and Valenciennes is not proper, as has been pointed out by de Beaufort (1951: 159).

*Acanthurus fraterculus* Cuvier and Valenciennes was described from a figure by Renard as brown with three oblique blue and red bands on each side of the head, a blue spot

below the middle of the dorsal fin, and green fins except the spinous dorsal which is blue and yellow. Although Günther (1861: 341) listed this species, he added that it had not been recognized.

*Chaetodon elongatus* Lacépède (1803: 454) is a special problem. It is a species of *Acanthurus*, and the type (No. A. 2506) is in the Paris Museum. L. Bertin (personal communication) writes that it is 90 mm. in standard length, has 16 upper teeth, and a caudal concavity of 4 mm. He adds that the specimen is dry, in very poor condition, and with no color markings perceptible. Günther (1861) listed *A. elongatus* as a questioned synonym of *Acanthurus nigrofuscus* (Forskål); the most frequent use of the name *elongatus* has been for *A. nigrofuscus*; however *A. elongatus* could not be this species. A 90 mm. specimen of *A. nigrofuscus* would have, at most, 12 upper teeth and would have a caudal concavity of about 16 mm. *Acanthurus elongatus* is probably a subadult of one of the larger species of *Acanthurus* such as *A. dussumieri* Cuvier and Valenciennes, *A. xanthopterus* Cuvier and Valenciennes, or *A. mata* (Cuvier). It is difficult to identify even fresh specimens of 90 mm. length of species in this complex. Because of the apparent juvenile nature and poor state of preservation of the type specimen, coupled with the inadequate original description, *elongatus* should be considered a *nomen inquirendum*.

*Acanthurus rackliffei* Schultz (1943: 157, 163, fig. 13) is probably a hybrid of *Acanthurus achilles* Shaw and *Acanthurus glaucopareius* Cuvier (Randall, in press, d).

Sauvage (1891: 519) listed *lunulatus* Liénard among the species of *Acanthurus* from Madagascar. I am unable to find the work of Liénard in which this species was described. This author was at times nonbinominal.

*Acanthurus doreensis* Cuvier and Valenciennes is here treated as a doubtful species.

Some species of *Acanthurus* have been described from the late postlarval or acronurus stage, and many of these were originally

placed in the genus *Acronurus* Gronow. The larval nature of *Acronurus* has been known at least since Günther (1873); nevertheless as recently as 1944 Fowler described a new species in the genus. It has not been possible in most cases for me to determine the correct adult name for species described from acronurus or early juvenile stages. The following such species I cannot place, with assurance, in synonymy: *Acronurus orbicularis* Quoy and Gaimard, *Acronurus fuscus* Gronow, *Acronurus anginosus* Bleeker, *Acronurus brevispinis* Günther, *Acronurus argenteus* Günther (not of Quoy and Gaimard), *Acronurus melanurus* Day, *Acronurus carneus* Poey, *Acronurus lineolatus* Klunzinger, *Acronurus machaeropterus* Fowler, *Acanthurus melanurus* Cuvier and Valenciennes, *Acanthurus melas* Cuvier and Valenciennes, *Hepatus leucopareius* Fowler (from Guam), *Teuthis elongatus* Kendall and Goldsborough, *Hepatus elegans* Kamohara (not of Garman), and *Teuthis spinifrons* Whitley.

I have been more successful in identifying to species actual museum specimens of acronurus forms and early juveniles. Some of these are shown in Figure 1. The adults of all of the species of *Acanthurus* are figured.

I have seen specimens of all of the known species of *Acanthurus* except *A. polyzona* (Bleeker), *A. leucocheilus* Herre, and *A. mindorensis* Herre. A. W. Herre has informed me that the types of the latter two were destroyed at Manila. To my knowledge there are no other specimens in existence. The specimens which Herre (1934: 62) identified as *A. leucocheilos* [us] are *Acanthurus pyroferus*.

Like most fishes, there are some obvious differences with age in species of *Acanthurus*. With increasing age, the eye becomes relatively smaller, the caudal fin generally more lunate, and in many species the body is more elongate; the teeth increase in number and at least in some species (see Table 16 under *A. gahhm*) the number of denticulations on the teeth decrease (for this reason the lengths are given for specimens from which teeth are taken for the tooth drawings of Fig. 2). Most

striking in many species are the color changes with age. Examples are as follows: the young of *A. coeruleus* Bloch and Schneider and *A. olivaceus* Bloch and Schneider are solid yellow in color; the distinctive mark found on the shoulder region of many of the species of *Acanthurus* is not present in juveniles; the semicircular black shoulder mark of *A. ten-nenti* Günther changes in older individuals to two elongate black bands; *A. achilles* does not develop its bright orange spot on the caudal peduncle until it has attained a size of about 65 to 70 mm.

Two keys are given, one to the Indo-Pacific species and one to the Atlantic species, not because there are any marked differences between the species of these two major regions, but as a convenience to the reader. The species are keyed out, insofar as possible, in natural groups (as based on superficial characters). These species groups are not sufficiently demarked from one another, in my opinion, to be regarded as subgenera. They are as follows:

1. *A. triostegus* (Linnaeus) and *A. polyzona* (Bleeker).
2. *A. nubilus* (Fowler and Bean), *A. bleekeri* Günther, and *A. thompsoni* (Fowler).
3. *A. nigrofuscus* (Forskål), *A. nigroris* Cuvier and Valenciennes, *A. leucopareius* (Jenkins), *A. guttatus* Bloch and Schneider, and possibly *A. coeruleus* Bloch and Schneider.
4. *A. lineatus* (Linnaeus) and *A. sobal* (Forskål).
5. *A. achilles* Shaw, *A. glaucopareius* Cuvier, and *A. leucosternon* Bennett.
6. *A. pyroferus* Kittlitz.
7. The remaining three Atlantic species and the last 11 Indo-Pacific species (*A. leucocheilus* and *A. mindorensis* not considered).

*A. pyroferus* is placed by itself because of its intermediacy between Groups 5 and 7; this is discussed in detail under *A. pyroferus*.

Group 7 constitutes a superspecific assemblage which has as its most characteristic



feature a large, round, thick-walled stomach. Such a gizzard-like stomach is not found in any other *Acanthurus* except *A. pyroferus*. These species are commonly found in bay or lagoon environments, and the gut contents generally contain a large percentage of hard, coarse, sedimentary material. The teeth tend to be elongate with numerous denticulations. Eight of the Indo-Pacific species develop with age a distinctive color mark in the shoulder region just above the gill opening. In most of the species the caudal spine is accentuated by being surrounded with color (often black or dark brown). They are not exclusive in this feature, however, for *Acanthurus achilles*, *Acanthurus sobal*, and certain species of *Naso*

serves as warning coloration, a means of calling attention to the sharp caudal spines. There is a tendency in this group toward large size, this being most apparent in *A. xanthopterus*, *A. dussumieri*, and *A. mata*.

It is only in this last group of species that I have observed sexual dimorphism in *Acanthurus*. Large adult males develop a definite convexity in the profile of the head above the mouth. Although there is a tendency for the profile to become more convex regardless of sex, it is much more evident in males than in females of the same size.

DISTRIBUTION

The distribution of the species of *Acanthurus* as indicated in the keys and Table 1 is based on localities of museum specimens seen by me and records from the literature about which there is little or no question. Further collecting may result in the extension of the range of some of the species.

Like most widely-distributed genera of tropical marine fishes, the greatest number of species of *Acanthurus* occurs in the Indo-Malayan region.<sup>2</sup> Twenty-three are recorded from the East Indies and Philippines, six of which are endemic to the area. This is a higher degree of endemism than that of any other region.

Only two species of *Acanthurus*, *A. achilles* and *A. leucopareius*, appear to be confined to oceanic islands of the Pacific. The latter is known by authentic records only from the Hawaiian Islands, Marcus Island, and Easter Island, areas widely separated and peripheral in Oceania, suggesting that *A. leucopareius* may be a relict species.

<sup>2</sup> The surgeon fish genera *Zebrasoma* and *Ctenochaetus*, however, do not follow this pattern. Of the six species of *Zebrasoma*, none are endemic to the Indo-Malayan region; two are confined to the Indian Ocean and two to the Pacific. Although two of the seven species of *Ctenochaetus* are restricted to the East Indies and Philippines, three are known only from islands in the central and eastern Pacific.

TABLE 1  
DISTRIBUTION OF THE SPECIES OF *Acanthurus*

MAJOR TROPICAL AND SUBTROPICAL REGIONS	NO. OF SPECIES KNOWN TO OCCUR IN REGION	NO. OF SPECIES CONFINED TO REGION
Indo-Pacific (28 species)		
Indian Ocean.....	13*	3†
Common to Indian Ocean and Indo-Malaya.....	12	2
Indo-Malayan region‡.....	23	6
Common to Indo-Malaya and Oceania.....	15	5
Oceania§.....	17	2
Common to Indian Ocean and Oceania.....	10	8
Eastern Pacific.....	3	0
Atlantic (4 species  )		
Western Atlantic.....	3	2
West Africa.....	2	1

\* *Acanthurus glaucopareius* is recorded from Christmas Island and Cocos-Keeling Islands in the Indian Ocean. Since these are near the East Indies and the species is unknown from the rest of the Indian Ocean, it is not included in this figure.  
† Includes *Acanthurus sobal*, a species known only from the Red Sea.  
‡ East Indies, northern Australia, Malaya, and Philippine Islands.  
§ Oceanic islands of the tropical western, southern, and central Pacific Ocean.  
|| The Indo-Pacific *Acanthurus triostegus* is not included in this figure, although there is one record of this species from West Africa.

have their caudal spines contained within areas of bright color. Presumably this color

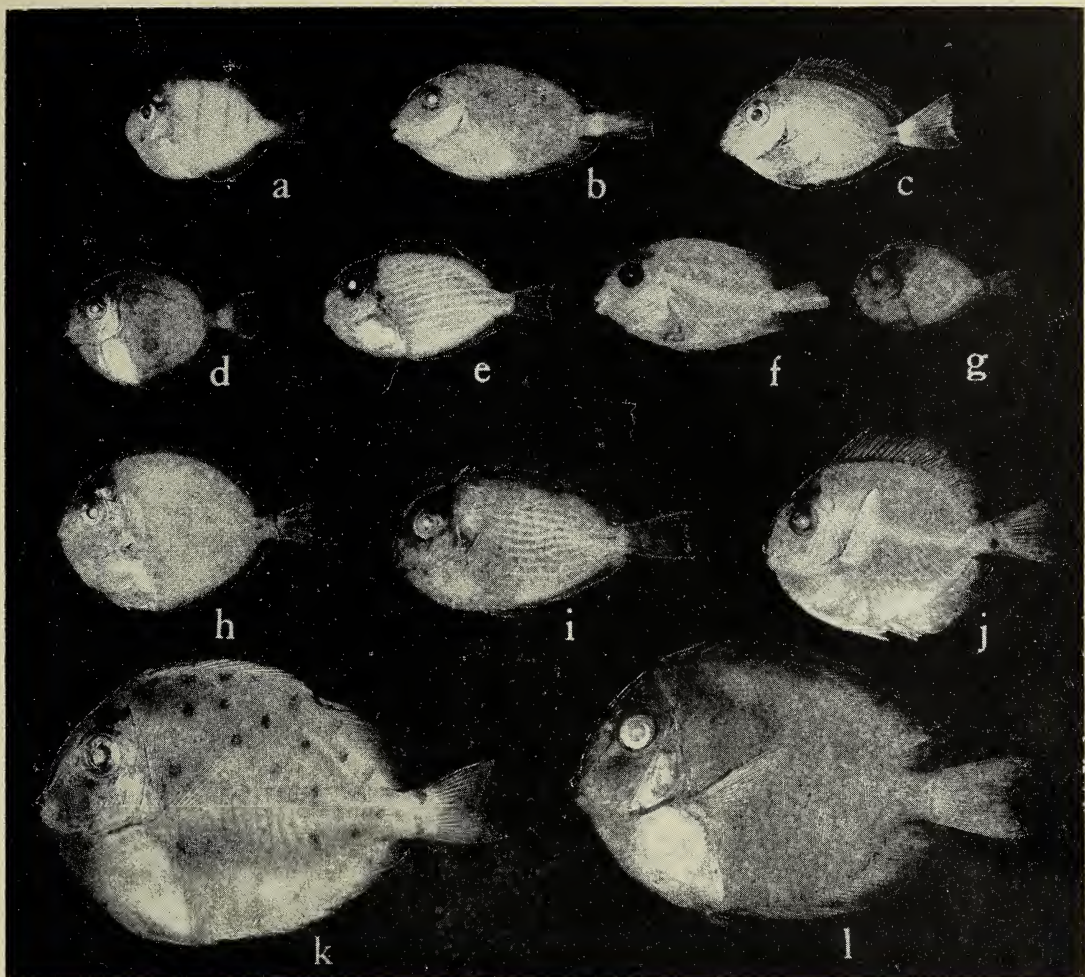


FIG. 1. *Acanthurus* and very young juvenile stages (as indicated) of species of *Acanthurus*: *a*, *triostegus triostegus*, Guam, U.S.N.M. No. 139750; *b*, *chirurgus*, Puerto Rico, U.S.N.M. No. 73825, (juvenile); *c*, *babianus*, Puerto Rico, U.S.N.M. No. 147648, (juvenile); *d*, *mata*, Oahu, Hawaiian Islands, U.S.N.M. No. 167248; *e*, *lineatus*, Mariana Islands, U.S.N.M. No. 139759; *f*, *olivaceus*, Eniwetok, Marshall Islands, U.S.N.M. No. 139998, (juvenile); *g*, *sobal*, Jidda, Red Sea, U.S.N.M. No. 147552; *h*, *dussumieri*, Oahu, Hawaiian Islands, U.S.N.M. No. 167247; *i*, *nigroris*, Wake Island, U.S.N.M. No. 167249; *j*, *guttatus*, Tau, Phoenix Islands, U.S.N.M. No. 115134; *k*, *achilles*, Oahu, Hawaiian Islands, U.S.N.M. No. 150744; *l*, *glaucoptereus*, Kwajalein, Marshall Islands, U.S.N.M. No. 139955.

*Acanthurus lineatus*, though widely distributed, is not reported from the Red Sea. The species which most resembles *A. lineatus* is *A. sobal*. The latter appears to be restricted to the Red Sea. *A. achilles* and the similar *A. leucosternon* are not recorded from the same area; *A. achilles*, as mentioned, seems to be characteristic of Oceania whereas *A. leucoster-*

*non* is an Indian Ocean and East Indian species. The Indian Ocean species *A. tennenti* is very closely related to *A. olivaceus*. The latter, however, does not seem to occur in the Indian Ocean, but ranges from the East Indies into the tropical Pacific. Although further collecting may result in the two species of these three pairs being found together, it may be





FIG. 2. Camera lucida drawings of upper (left) and lower (right) teeth of various species of *Acanthurus*. Teeth were taken from right side of jaws near center and drawn in inner or lingual view. *a*, *triostegus*, 140 mm. specimen, Marshall Islands; *b*, *nubilus*, 156 mm. specimen, East Indies; *c*, *bleekeri*, 223 mm. specimen, Philippine Islands; *d*, *thompsoni*, 138 mm. specimen, Gilbert Islands; *e*, *guttatus*, 165 mm. specimen, Gilbert Islands; *f*, *leucopareius*, 156 mm. specimen, Hawaiian Islands; *g*, *nigroris*, 81 mm. specimen, Marshall Islands; *h*, *nigrofuscus*, 81 mm. specimen, Marshall Islands; *i*, *lineatus*, 150 mm. specimen, Gilbert Islands; *j*, *sobal*, 203 mm. specimen, Red Sea; *k*, *pyroferus*, 143 mm. specimen, Philippine Islands; *l*, *leucosternon*, 173 mm. specimen, Mauritius; *m*, *glaucoptareius*, 143 mm. specimen, Marshall Islands; *n*, *achilles*, 137 mm. specimen, Phoenix Islands; *o*, *olivaceus*, 190 mm. spec-

worth noting at this time that they may be species which will not co-exist due to similarities in ecological tolerances (Gause, 1934). I suspect that this may be the explanation because of the apparent ease with which species of *Acanthurus* achieve wide distribution (probably because of long planktonic larval life). Since *A. olivaceus*, for example, ranges from the East Indies throughout Oceania, it would be expected to occur also in the Indian Ocean in view of existing current patterns.

The possibility that two species of *Ctenochaetus* may be mutually exclusive also bears checking. *C. magnus* Randall is known thus far from only three localities, Jarvis Island, Malden Island, and Cocos Island (off Costa Rica). The usually abundant *C. striatus* (Quoy and Gaimard) has not been collected from any of these islands, although it would not be expected at Cocos since this species does not appear to be among the few surgeon fishes to have crossed the Eastern Pacific Barrier (see Ekman, 1953).

One of the Atlantic species, *Acanthurus chirurgus* (Bloch) is very similar to the Indo-Pacific *A. xanthopterus* which occurs on the Pacific coast of Mexico and Central America, where it has usually been known by the name *Acanthurus crestonis* (Jordan and Starks). Although not included among the geminate species (listed by Jordan 1908: 76) which occur on either side of the isthmus of Panama, these two might qualify as another example.

The three Atlantic species which are common in the West Indies and Florida are occasionally taken as far north as New York and Massachusetts. It is believed that these species are not resident in such northern localities but represent individuals carried northward as larvae by the Gulf Stream.

The acronurus of *Acanthurus triostegus* is

taken farther south on the southeast coast of Africa than are adults (Smith, 1949: 240 and by personal communication). The strong southerly current in this region is probably responsible. The same thing appears to be true of several species of surgeon fishes on the east coast of Australia (Whitley, 1953).

#### METHODS OF COUNTING AND MEASURING

Each ray of the dorsal and anal fins with a distinct base was counted regardless of how close adjacent rays might be. In cases where two rays branch from a common base, they were counted as one. At times dissection was necessary to determine whether the last two rays originate from a single basal element. Pectoral fin ray counts include the two uppermost unbranched rays, the first of which is a short bony spicule.

The gill rakers are small and occur in two distinct series, one on each side of the gill arch. Counts of both series are of diagnostic importance in *Acanthurus*. The usual gill raker counts are here designated anterior; those on the posteromedial side of the arch are called posterior. Gill raker counts were made on the first arch and include all rudiments. The raker counts were made on five specimens unless otherwise stated.

The scales are small and do not occur in regular rows. Successive trials at counting scales on the same specimen rarely resulted in the same count. The only scale counts which are recorded are those for the one new species.

The standard length is measured from the tip of the snout to the base of the caudal fin (end of hypural plate). All references to length of specimens are standard length. Head length is taken from the tip of the snout horizontally to a vertical at the most posterior end of the

imen, Marshall Islands; *p. tennenti*, 115 mm. specimen, locality unknown; *q. fowleri*, 198 mm. specimen, Philippine Islands; *r. bariene*, 169 mm. specimen, Philippine Islands; *s. gabhm*, 179 mm. specimen, Phoenix Islands; *t. maculiceps*, 194 mm. specimen, Gilbert Islands; *u. auranticavus*, 205 mm. specimen, Philippine Islands; *v. grammoptilus*, 204 mm. specimen, Philippine Islands; *w. dussumieri*, 210 mm. specimen, Hawaiian Islands; *x. xanthopterus*, 200 mm. specimen, Gilbert Islands; *y. mata*, 228 mm. specimen, Wake Island; *z. monroviae*, 192 mm. specimen, Liberia; *aa. coeruleus*, 127 mm. specimen, Haiti; *bb. chirurgus*, 178 mm. specimen, Cuba; *cc. bahianus*, 168 mm. specimen, Cuba.



opercular membrane. Body depth is the distance from the natural groove at the base of the second anal spine to a similar groove at the base of the dorsal fin. Caudal concavity is the distance between vertical lines passing through the tips of the shortest middle caudal rays and the longest ray of the dorsal lobe of the caudal fin. This measurement is not made from a compressed or stretched caudal fin, but one in the normal resting position as shown in the figures of the various species.

### ACANTHURUS Forskål

*Acanthurus* Forskål (1775: 59). Type species by subsequent designation (Jordan, 1917), *Chaetodon sobal* Forskål.

Body compressed, elliptic, the depth contained 1.55 to 2.5 in standard length; head length 3 to 4.3 in standard length; caudal peduncle with a single sharp folding spine on each side, fitting into a definite socket; length of caudal spine 1.9 to 13 in head length; least depth of caudal peduncle 1.9 to 3.1 in head length; mouth small, terminal, and only slightly protractile; jaws equal; teeth close-set, compressed, denticulate, 8 to 24 in upper jaw and 10 to 24 in lower jaw; dorsal fin with VI to IX (usually IX) spines and 22 to 33 rays; anal fin with III spines and 19 to 29 rays; pectoral fin rays 15 to 17; pelvic fin with I spine and 5 rays; caudal fin with 16 principal rays; caudal fin varying in shape from nearly truncate to very lunate; dorsal and anal fins continuous and unnotched; longest dorsal ray 3.5 to 6 in standard length; longest anal ray 3.8 to 7 in standard length; length of pectoral fin 2.7 to 3.8 in standard length; length of pelvic fin 3.2 to 5.5 in standard length; origin of pelvic fin at or slightly posterior to a vertical through middle of base of pectoral fin; diameter of eye in adults 2.8 to 5.7 in head length; interorbital space 2.5 to 3.6 in head length; snout length 3.9 to 8.2 in standard length; gill openings restricted to sides; gill membranes attached to isthmus; anterior gill rakers 13 to 29; posterior gill

rakers 13 to 32; scales ctenoid, very small, and not in regular rows; head scaled, though not conspicuously; lateral line complete; 22 or 23 vertebrae; stomach varies from round and heavy-walled to elongate and thin-walled.

Agassiz (1833-43: vol. 4, p. 207, pl. J) discussed the osteology of *Acanthurus*. Günther (1861: 327) described the osteology of *Acanthurus triostegus*, and Gregory (1933: fig. 156) figured the skull of this species. Souche (1935) made an anatomical study of the musculature of the caudal spine of *Acanthurus chirurgus*. Willem (1944) studied the respiratory system of *Acanthurus triostegus* along with that of other species.

Plate 5, figures 3, 4, and 5 of Lütken (1880) represent the postacronurus, acronurus, and postlarval forms, respectively, of *Acanthurus coeruleus*. His figure 5 was drawn from a 5.7 mm. specimen. Weber (1913: fig. 70) figured a 7 mm. postlarval stage of an unidentified species of *Acanthurus*.

The genus *Acanthurus* is known by the common names surgeon fish, doctor fish, and tang. The species are, in general, herbivorous.

The gender of the name *Acanthurus* is uncertain. The probable derivation of this generic name is from the Greek *acantha* (thorn, fem.) and the Greek *oura* (tail, fem.). If properly latinized, it would have been *Acanthura*. Forskål, who proposed the name more-or-less as a subgenus and never used it in combination with a specific name, probably intended that it be masculine. Subsequent authors, including those who wrote primarily in latin, have consistently treated the genus as masculine, and I concur in this.

For a review of the generic synonymy of *Acanthurus* and a key to all the genera of the Acanthuridae, see Randall (1955a).

### KEY TO THE SPECIES OF *Acanthurus* OF THE INDIAN AND PACIFIC OCEANS

(See page 165 for methods of counting and measuring.)

- 1a. Body light in color with vertical black bars; caudal fin truncate or slightly

- emarginate, caudal concavity contained more than 15 times in standard length; caudal spine very small. . . . . 2
- 1b. Body not light in color with vertical black bars; caudal fin, at least in adults, emarginate to lunate, caudal concavity contained less than 15 times in standard length (except *guttatus*); caudal spine usually not small. . . . . 3
- 2a. 6 vertical black bars (1 on head passing through eye; 4 on side of body; 1 on caudal peduncle); bars on side of about uniform width; anal soft rays 19 to 22; dorsal soft rays 22 to 24 (excluding fin ray counts of the species in Hawaii). (Indo-Pacific). . . . *triostegus*
- 2b. 12 vertical black bars (4 on head, the longest passing through eye; 6 on side of body; 2 on caudal peduncle); bars on side about five times as broad dorsally as ventrally; anal soft rays 21 to 23; dorsal soft rays 23 to 25. (Réunion Island, Indian Ocean) (after Bleeker). . . . . *polyzona*
- 3a. Snout short, its length contained 6.6 to 8.2 times in standard length; mouth small and teeth small and numerous, 22 or more in lower jaw of adults. . . . . 4
- 3b. Snout not short, its length contained 3.9 to 5.3 times in standard length; mouth usually not small (if small, not more than 12 teeth in lower jaw) and teeth not small and numerous, 22 or less (rarely 22) in lower jaw of adults. . . . 6
- 4a. Dorsal spines VI or VII; body depth 1.8 in standard length; anterior gill rakers 21; posterior gill rakers 24 (based on 1 specimen). (Philippine Islands and East Indies). . . . . *nubilis*
- 4b. Dorsal spines IX; body depth 2.1 to 2.5 in standard length; anterior gill rakers 13 to 17; posterior gill rakers 13 to 15. 5
- 5a. Lengthwise blue lines on side of head and body (may be faded in preserved specimens); snout 6.6 to 7.1 in standard length; least depth of caudal peduncle 2.7 to 3 in head length; no dark brown spot just below axil of pectoral fin; maximum standard length about 300 mm. (Indo-West-Pacific, except Hawaii). . . . . *bleekeri*
- 5b. No lengthwise blue lines on side of head and body; snout 7.9 to 8.2 in standard length; least depth of caudal peduncle 2.2 to 2.5 in head length; a dark brown spot just below axil of pectoral fin; maximum standard length about 150 mm. (East Indies, Philippine Islands, and Oceania). . . . *thompsoni*
- 6a. Mouth low in origin on head and produced; a deep brown ring at base of caudal fin; all fins black. (Philippine Islands) (after Herre). . . *mindorensis*
- 6b. Mouth not low in origin on head and usually not produced; no deep brown ring at base of caudal fin; all fins not black. . . . . 7
- 7a. Posterior half of body and dorsal and anal fins with numerous white spots on a brown background; body with 3 vertical whitish bars, the first running from occiput to opercle, the second from base of third and fourth dorsal spines to region of anus, and the third from base of first few dorsal soft rays to base of first few anal soft rays; body very deep, greatest depth 1.5 to 1.6 in standard length. (Indo-West-Pacific). . . *guttatus*
- 7b. Posterior half of body without numerous white spots; body without 3 vertical whitish bars; body not very deep, greatest depth 1.7 to 2.5 in standard length. 8
- 8a. A black spot at base of last few rays of both the dorsal and anal fins (spot in axial of anal fin in *leucopareius* very small). . . . . 9



- 8b. No black spot at base of last few rays of dorsal and anal fins . . . . . **11**
- 9a. A whitish band, broadly bordered by dark brown bands, running from origin of dorsal fin across operculum just behind eye (faded in some specimens); caudal fin with no white posterior margin; caudal fin emarginate, caudal concavity 10.5 to 12 in standard length of adults; body depth 1.7 to 1.8 in standard length; anterior gill rakers 15 to 18. (Hawaiian Islands, Marcus Island, and Easter Island) . . . . . **leucopareius**
- 9b. No whitish band running from origin of dorsal fin across operculum; caudal fin with a white posterior margin; caudal fin moderately concave to lunate, caudal concavity 4.5 to 10 in standard length; body depth 1.8 to 2.3 in standard length; anterior gill rakers 20 to 29. . . . . **10**
- 10a. Caudal fin moderately concave, caudal concavity 5.8 to 10.5 in standard length; black spot at axil of soft dorsal fin not large, its greatest width contained more than 2 times in diameter of eye; white posterior margin of caudal fin narrow, its width rarely less than 4 in pupil; no definite black margin around groove of caudal spine; body depth 1.8 to 2 in standard length; ends of median upper teeth rounded (Fig. 2g); maximum standard length about 200 mm.; no orange spots on head in life. (East Indies, Philippine Islands, and Oceania) . . . . . **nigroris**
- 10b. Caudal fin lunate, caudal concavity 4.5 to 6 in standard length; black spot at axil of soft dorsal fin large, its greatest width contained less than 2 times in diameter of eye; white posterior margin of caudal fin not narrow, its greatest width about 2 in pupil (in specimens from Oceania); a definite black margin around groove of caudal spine; body depth 2 to 2.3 in standard length; ends of median upper teeth tend to be pointed (Fig. 2b); maximum standard length about 150 mm. (rarely over 120 mm.); orange spots on head in life (which usually fade in preservative). (Indo-West-Pacific) . . . . . **nigrofuscus**
- 11a. Upper  $\frac{3}{4}$  of body with conspicuous lengthwise black bands and in sharp contrast to uniform light grayish brown of lower  $\frac{1}{4}$ ; caudal spine very long (1.9 to 2 in head length) and without a definite sheath; posterior gill rakers 13 to 15; anterior gill rakers 14 to 17. . . . . **12**
- 11b. Body without conspicuous lengthwise black bands; caudal spine not very long (2.1 to 8 in head length) and with a definite sheath; posterior gill rakers 17 to 32; anterior gill rakers 16 to 29. . . . . **13**
- 12a. Dorsal rays IX, 27 to 29; about 7 black lengthwise bands on body below lateral line (anteriorly), each bisected with a blue line and alternating with whitish (yellow in life) lines; median and pelvic fins not black. (Indo-West-Pacific, but not Hawaii) . . . . . **lineatus**
- 12b. Dorsal rays VIII, 30 to 31; about 15 black lengthwise bands on body below lateral line (anteriorly), none bisected with blue lines and not alternating with whitish lines (the narrow intermediate lines of same color as ventral part of body); median and pelvic fins black. (Red Sea) . . . . . **sohal**
- 13a. Lips reddish in life and surrounded (or nearly surrounded) by a pearly white line with a black band behind it; a bluish white band of about a half an eye diameter in thickness crossing chest slightly anterior to a vertical through center of eye; outer part of soft dorsal fin in life with 3 and anal fin with 2 narrow red lines alternating with bluish lines; pelvic fins brick red with black outer margin. (Philippine Islands) (after Herre) . . . . . **leucocheilus**

- 13b. Lips not reddish in life and never completely surrounded by a pearly white line with a black band behind it; no bluish white band of about a half an eye diameter in width crossing chest; no red lines in outer part of soft dorsal and anal fins; pelvic fins not brick red with black outer margin. . . . . 14
- 14a. Dorsal spines VIII; caudal fin black except for a broad pale (yellow in life) band of near-uniform width on entire posterior margin (hence most of prolonged outer lobes of caudal fin pale); a white line under chin extending slightly above rictus; upper end of gill opening and edge of operculum broadly black; a diffuse orange area in life behind gill opening extending to axil of pectoral fin. (Indian Ocean, East Indies, Philippine Islands, and Western Oceania) . . . . . *pyroferus*
- 14b. Dorsal spine IX; caudal fin not black with a broad pale posterior margin of uniform width; upper end of gill opening and edge of operculum not broadly black; no diffuse orange area in life behind gill opening extending to axil of pectoral fin. . . . . 15
- 15a. Mouth very small, its width from rictus to rictus contained 4.5 to 6 times in length of head; maximum number of upper or lower teeth 12; a white line under chin; depth of body 1.7 to 1.9 in standard length; dorsal soft rays 28 to 33; anal soft rays 26 to 29. . . . . 16
- 15b. Mouth not very small, its width from rictus to rictus contained 3.2 to 4.8 times in length of head; maximum number of upper or lower teeth 22 (specimens over 50 mm. in standard length with at least 14 teeth in either jaw); no white line under chin; depth of body 1.9 to 2.5 in standard length; dorsal soft rays 23 to 28; anal soft rays 22 to 26. 18
- 16a. Isthmus and chest with a chalky white band (as broad as depth of caudal peduncle) extending to base of pectoral fin; body bluish gray in preservative, head dark brown. (East Indies and Indian Ocean) . . . . . *leucosternon*
- 16b. Isthmus and chest without a broad white band; body and head dark brown to black. . . . . 17
- 17a. No large elliptical pale yellowish area posteriorly on body; an oval white spot under eye; no white mark on opercular membrane; white line on chin extending above rictus; pale area at base of dorsal and anal fins very broad posteriorly; caudal fin emarginate, caudal concavity 10 to 14.5 in standard length; dorsal soft rays 28 to 31 (usually 29 or 30); anal soft rays 26 to 28 (usually 26 or 27). (East Indies, Philippine Islands, Oceania, and islands of tropical eastern Pacific) . . . . . *glaucopterus*
- 17b. A large elliptical pale yellowish area (bright orange in life) posteriorly on body, enclosing in its hind part the caudal spine (this area absent in specimens less than about 65 to 70 mm. in standard length); no oval white spot under eye; an elongate pure white mark on opercular membrane; white line on chin not extending above rictus; pale area at base of dorsal and anal fins narrow and of almost uniform width; caudal fin lunate, caudal concavity 5.5 to 8.5 in standard length; dorsal soft rays 29 to 33 (usually 30 to 32); anal soft rays 26 to 29 (usually 27 to 29). (Oceania). . . . . *achilles*
- 18a. A prominent dark mark on shoulder (absent in young) . . . . . 19
- 18b. No dark mark on shoulder. . . . . 25
- 19a. Shoulder mark semicircular (open end forward at level of eye), a very elongate horizontal ellipse, or two elongate bands



- (one above the other); a large crescent-shaped white region posteriorly in caudal fin, its greatest width more than half the diameter of eye; base of caudal fin not pale; anal soft rays 22 to 24; dorsal soft rays 23 to 25; no fine longitudinal lines on body . . . . . **20**
- 19b. Shoulder mark a spot, horizontal solid bar, or open triangle or semicircle (open part forward and below level of eye); no large crescent-shaped white region posteriorly in caudal fin (a white posterior margin, if present, of a maximum width of less than  $\frac{1}{3}$  eye diameter); base of caudal fin pale; anal soft rays 23 to 26; dorsal soft rays 24 to 28; fine longitudinal lines may or may not be present on body . . . . . **21**
- 20a. Shoulder mark elongate with pale yellowish (bright orange in life) center; no dark area around caudal spine; white crescent in caudal fin with a narrow black posterior margin; brown portion of caudal fin with dark brown spots; color of young in life solid yellow (pale in preservative). (East Indies, Philippine Islands, and Oceania) . . **olivaceus**
- 20b. Shoulder mark semicircular with no pale center or (at a size of 100 to 110 mm. or more in standard length) 2 elongate black bands; a black, light bluish-bordered area around caudal spine (this area becoming relatively larger in larger specimens); white crescent in caudal fin without a black posterior margin; caudal fin without brown spots; color of young unknown to me. (Ceylon and Mauritius) . . . . . **tennenti**
- 21a. Shoulder mark triangular or semicircular with uppermost part just above dorsal end of gill opening and lower part near axil of pectoral fin; posterior gill rakers 29 to 32. (East Indies and Philippine Islands) . . . . . **fowleri**
- 21b. Shoulder mark a spot or solid bar; posterior gill rakers 17 to 28 . . . . . **22**
- 22a. Shoulder mark a round black spot (just behind eye), at times with a narrow light bluish border; a blue line at base of dorsal fin in life, usually persisting as a bluish white line on preserved specimens; depth of body 1.9 to 2 in standard length. (East coast of Africa, East Indies, Philippine Islands, and Riu Kiu Islands) . . . . . **bariense**
- 22b. Shoulder mark a black or dark brown bar; no blue line at base of dorsal fin in life; depth of body 2 to 2.2 in standard length . . . . . **23**
- 23a. Caudal fin with a distinct white posterior margin, broader centrally, about  $\frac{1}{4}$  eye diameter in maximum width; a long, pointed, black streak extending anteriorly from caudal spine (first appearing at a size of about 100 mm. and becoming progressively longer in larger specimens until it extends over half distance from caudal spine to base of pectoral fin); length of black shoulder bar (in specimen over 100 mm. in standard length) about 4.5 to 7 in standard length; numerous pale lengthwise lines not present on body; anal soft rays 24 to 26; dorsal soft rays 25 to 28. (Indo-West-Pacific) . . . . . **gahhm**
- 23b. Caudal fin without a distinct white posterior margin; no long, pointed, black streak extending anteriorly from caudal spine; length of dark shoulder bar about 9 to 13 in standard length; numerous pale lengthwise lines present on body (faint on some specimens); anal soft rays 23 to 24; dorsal soft rays 24 to 26 . . . . . **24**
- 24a. Head and nape with numerous prominent pale spots; upper distal part of pectoral fin with a large pale yellowish spot; shoulder mark in back of gill

- opening black (indistinct above and anterior to gill opening), horizontal, and usually somewhat pointed at end; dorsal fin with about 9 narrow longitudinal bands from base to margin; posterior gill rakers 21 to 24. (East Indies, Philippine Islands, and Gilbert Islands) . . . . . **maculiceps**
- 24b. Head and nape without pale spots; upper distal part of pectoral fin without a large pale spot; shoulder mark dark brown (indistinct and narrow above gill opening), tilting sharply downward as it passes posteriorly, and rounded at end; dorsal fin without lengthwise bands or with only one or two posteriorly near outer border; posterior gill rakers 25 to 28. (Philippine Islands and East Indies) . . . . . **auranticavus**, n. sp.
- 25a. Head with small pale (rust color in life) spots; black around caudal spine groove of adults extending ahead of front end of spine (to a distance almost as long as spine in a 245 mm. specimen); caudal fin with a very narrow white posterior margin (broader in young); body depth of adults (over 200 mm. in standard length) 2.2 to 2.5 in standard length. (northern Australia) . . . **grammoptilus**
- 25b. Head without small pale spots; dark brown or black around groove of caudal spine not extending much beyond front end of spine; caudal fin without a narrow white posterior margin (except in young which may have a very narrow pale margin); body depth of adults 1.9 to 2.1 in standard length . . . . . 26
- 26a. Caudal fin marked with numerous blackish spots; sheath of caudal spine whitish and in sharp contrast to black surrounding caudal spine groove; a pale (yellow in life) band crossing or nearly crossing interorbital space from eye to eye; body with numerous, fine, slightly wavy, pale bluish, lengthwise lines which usually persist in preservative; dorsal fin of adults without alternating dark and light bands or with only a few faint narrow ones in outer portion of fin; eye large, its greatest diameter contained in head length about 3.2 to 4.7 times over the range in standard length of 120 to 300 mm.; anal soft rays 24 to 26. (Indo-West-Pacific) . . . . . **dussumieri**
- 26b. Caudal fin not marked with blackish spots; sheath of caudal spine brownish; no pale band crossing interorbital space (a pale yellowish area may extend anteriorly from eye but not as a definite band); body without numerous slightly wavy, fine, pale bluish, lengthwise lines (lines, if present, indistinct and broken or coarse and very wavy and rarely evident in preserved specimens); dorsal and anal fins with lengthwise dark brown (blue in life) bands alternating with light brown (yellow in life) bands from base to margin (may fade in preservative, especially in *mata*); eye not large, its greatest diameter contained about 3.9 to 5.4 times in head length over the range in standard length of 120 to 300 mm.; anal soft rays 23 to 25 . . 27
- 27a. Outer  $\frac{1}{3}$  of pectoral fin pale (yellowish in life) and contrasting with darker basal  $\frac{2}{3}$  of fin (in specimens over about 120 mm. in standard length); dorsal fin with about 4 broad lengthwise bands; caudal fin very lunate, caudal concavity about 4.5 to 7 in standard length; caudal spine usually small, about 4.5 to 5.5 in length of head; dark margin around socket of caudal spine usually narrow and indistinct; white band at base of caudal fin usually not distinct; anterior gill rakers 16 to 22; posterior gill rakers 17 to 22. (Indo-Pacific) . . . . . **xanthopterus**
- 27b. Pectoral fin uniform brown; dorsal fin (at least in Hawaiian specimens) with about 8 narrow lengthwise bands; cau-



dal fin not very lunate, caudal concavity about 6 to 10 in standard length; caudal spine usually not small, about 3 to 4.2 in length of head; a definite dark brown or black margin around socket of caudal spine forming an area about twice as high as maximum width of spine; white band at base of caudal fin usually distinct; anterior gill rakers 21 to 25; posterior gill rakers 23 to 25. (Indo-West-Pacific) . . . . . **mata**

KEY TO THE SPECIES OF *Acanthurus*  
OF THE ATLANTIC OCEAN

- 1a. Body very pale with 6 vertical black bars, the first passing through eye, the last dorsally on caudal peduncle; anal soft rays 19 to 21; dorsal soft rays 22 to 24. (Indo-Pacific, one record from West Africa) . . . . . **triestegus**
- 1b. Body not very pale with 6 vertical black bars; anal soft rays 22 to 26; dorsal soft rays 24 to 28 . . . . . **2**
- 2a. A very large pale (yellow or orange in life) spot on caudal peduncle with caudal spine in center. (West Africa) . . . . . **monroviae**
- 2b. No large pale spot on caudal peduncle. **3**
- 3a. Anal soft rays 24 to 26; dorsal soft rays 26 to 28 (usually 27); body depth about 1.7 in standard length; no narrow dark area around caudal spine; sheath of caudal spine pale; body purplish in life with conspicuous lengthwise lines (in young bright yellow without lines); anterior gill rakers 13 to 14. . . . . **coeruleus**
- 3b. Anal soft rays 21 to 23; dorsal soft rays 23 to 26 (rarely 26); body depth about 2 in standard length; a narrow dark area (blue in life) around caudal spine; sheath of caudal spine dusky; body light to dark brown in life with or without faint narrow lengthwise lines; anterior gill rakers 16 to 19 . . . . . **4**

- 4a. Eight to 12 dark brown vertical bars on side of body; caudal fin emarginate (nearly truncate in young), caudal concavity contained about 14 to 18 times in standard length; caudal fin without a definite white posterior margin; outer  $\frac{1}{3}$  of pectoral fin pale in adults; no fine lengthwise lines on body; posterior gill rakers 15 to 18 . . . . . **chirurgus**
- 4b. No dark brown vertical bars on side of body; caudal fin lunate, caudal concavity contained about 5 to 12 times in standard length; caudal fin with a whitish posterior margin, broadest centrally (about  $\frac{1}{4}$  to  $\frac{1}{3}$  pupil diameter in width in adults, greater in young); outer  $\frac{1}{3}$  of pectoral fin not distinctly paler than rest of fin; fine lengthwise lines on body (which usually fade in preservative); posterior gill rakers 22 to 24 . . . . . **bahianus**

*Acanthurus triostegus* (Linnaeus)  
Figs. 1a, 2a, 3, 4

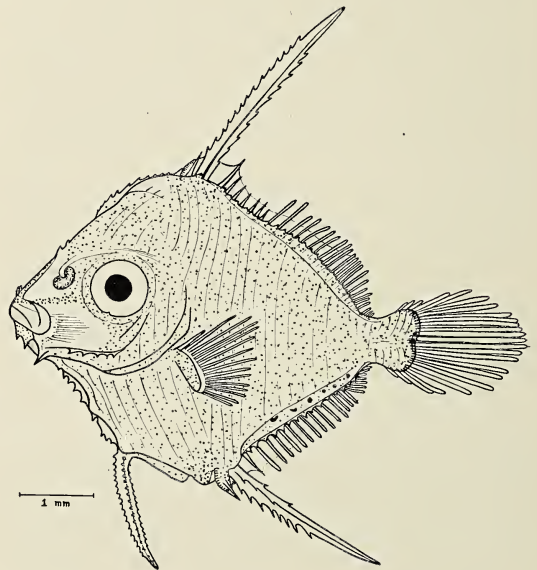


FIG. 3. Postlarval *Acanthurus triostegus sandvicensis*. Drawn with the aid of a camera lucida by Helen A. Randall (specimen taken in a plankton tow, offshore, Hawaiian Islands).

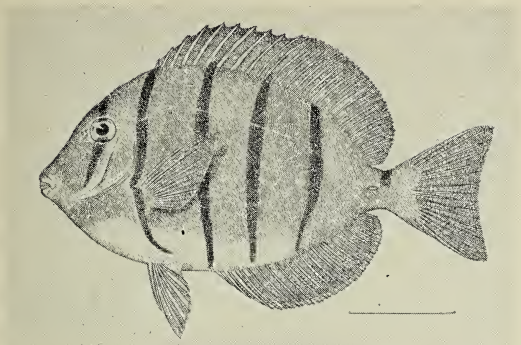


FIG. 4. *Acanthurus triostegus sandvicensis* (after Jordan and Evermann, 1905, retouched).

- Chaetodon triostegus* Linnaeus (1758: 274) (Indies).
- Harpurus fasciatus* Forster (1788) (reference after Jordan 1917).
- Acanthurus Triostegus* Bloch and Schneider (1801: xxxviii, 215) (Indian and Pacific Oceans).
- Acanthurus zebra* Lacépède (1802: 546) (Pacific Ocean and East Indies).
- Chaetodon couaga* Lacépède (1802: 726, 727, pl. 6, middle fig.).
- Teuthis australis* Gray (1827: 435) (Australia).
- Acanthurus hirudo* Bennett, J. W. (1828: pl. 11) (Ceylon).
- Acanthurus triostegus* Cuvier and Valenciennes (1835: 197) (Mauritius, Seychelles, Marianas, New Zealand, Oualan, Society Islands, and Hawaiian Islands); Bleeker (1850a: 13) (Batavia, Java); Günther (1861: 327) (East Indies, New Hebrides, Mauritius, New Zealand, west coast of Australia, and Hawaiian Islands); Playfair in Playfair and Günther (1866: 56) (Zanzibar); Günther (1873: 108) (Indian Ocean and Polynesia); Day (1876: 204, pl. 48, fig. 2) (seas of India); Macleay (1881: 527) (west coast of Australia); Steindachner (1882: 54) (Congo Coast, West Africa); Hilgendorf (1883: 43); Day (1889: 139, fig. 54); Waite (1894: 217) (Maroubra, New South Wales); Waite (1897: 187) (Funafuti, Ellice Islands); Weber (1913: 316) (East Indies); Herre (1927: 407, pl. 1, fig. 1) (Philippine Islands and Guam); Herre (1936: 240) (Cocos Island off Costa Rica, Marquesas Islands, Tuamotu Archipelago, Tahiti, Fiji Islands, and New Hebrides); Brock (1943: 130) (Tres Marias Islands, Mexico); Schultz (1943: 162) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 33, no. 608) (east coast of Africa south to Zululand); de Beaufort (1951: 144) (East Indies); Harry (1953: 146) (Raroia, Tuamotu Archipelago).
- Acanthurus triostegus* Swainson (1839: 255) (error for *triostegus*).
- Acanthurus Subarmatus* Bennett, F. D. (1840: 278, fig.) (Society Islands).
- Acanthurus pentazona* Bleeker (1850a: 4, 13) (Batavia, Java); Bleeker (1850b: 107) (Batavia, Java); Günther (1861: 329).
- Rhomboides triostegus* Bleeker (1863b: 235) (Ternate, East Indies).
- Rhomboides pentazona* Bleeker (1865: 288) (Ambon, East Indies).
- Acanthurus triostegus* var. *sandvicensis* Streets (1877: 67) (Honolulu).
- Acanthurus zebra* DeVis [not of Lacépède] (1883: 447) (Duke of York Group = Tokelau Islands).
- Teuthis triostegus* Jordan and Evermann (1898: 1690) (Clarion and Socorro Islands, western Mexico); Seale (1901: 108) (Guam); Jordan and Evermann (1902: 357) (Kotosho Island, Formosa); Jordan and Fowler (1902: 552) (Okinawa); Kendall and Goldsborough (1911: 309) (Tuamotu Archipelago and Marshall Islands); Kendall and Radcliffe (1912: 144) (Manga Reva); Barnard (1927: 778, pl. 31, fig. 5) (Natal coast, Africa); Marshall, T. C. (1941: 62) (Moreton Bay and Townsville, Queensland); Fowler (1944b: 172) (New Hebrides); Fowler (1945: 66) (Saipan).
- Teuthis elegans* Garman (1899: 70, pl. L, fig. 2) (Cocos Island off Costa Rica).
- Teuthis sandvicensis* Jenkins (1903: 479) (Hawaiian Islands); Snyder (1904: 533) (Hawaiian Islands); Fowler (1941: 257) (Oahu); Fowler (1949: 104).



*Hepatus sandvicensis* Jordan and Evermann (1905: 394, fig. 172) (Hawaiian Islands); Jordan and Seale (1906: 354) (Hawaii).

*Hepatus triostegus* Snodgrass and Heller (1905: 403) (Revillagigedo Islands and Cocos Island); Jordan and Seale (1906: 354) (Samoa); Steindachner (1906: 1392) (Samoa Islands); Ogilby (1916: 184) (coast of Queensland); Fowler and Silvester (1922: 124) (Samoa); Fowler and Ball (1925: 19) (Laysan, Lisiansky, French Frigate Shoals, and Necker Island in the Hawaiian Archipelago, Johnston Island, and Wake Island); Fowler (1928: 264, pl. 31, fig. A) (Indo-Pacific); Fowler and Bean (1929: 249) (Indo-Pacific); Fowler (1932: 10) (Marquesas Islands); Seale (1935: 364) (Solomon Islands); Fowler (1938: 173, 184) (Bora Bora and Tongareva); Pietschmann (1938: 26, pl. 4) (Molokai and Pearl and Hermes Reef, Hawaiian Archipelago); Schmidt and Schultz (1940: 8) (Clipperton Island); Hi-yama (1943: 95, pl. 20, fig. 57) (Marshall Islands); Aoyagi (1943: 216, pl. 6, fig. 16, teeth only) (Riu Kiu Islands); Kamohara (1954: 52) (Tokara Islands, southern Japan).

*Acanthurus sandvicensis* Jordan and Jordan (1922: 66) (Hawaiian Islands); Schultz and Woods (1948: 248, fig. 1, A) (Hawaiian Islands and Johnston Island).

*Tenthis troughtoni* Whitley (1928: 233, pl. 16, fig. 1) (Vanikoro, Santa Cruz Islands); Whitley and Colefax (1938: 294, fig. 3) (Nauru Island and Ocean Island); Fowler (1946: 197) (Riu Kiu Islands).

*Acanthurus triostegus* Borodin (1932: 87) (Samoa, Bora Bora, and Raiatea) (error for *triostegus*).

*Acanthurus triostegus triostegus* Schultz and Woods (1948: 249, fig. 1, B) (Indo-Pacific); Schultz and Woods in Schultz *et al.* (1953: 624, fig. 90, b, d, e, pl. 63, A, B, C, pl. 64, A, B, C) (Marshall and Mariana Islands).

*Acanthurus triostegus marquesensis* Schultz and Woods (1948: 250, fig. 1, C, F) (Marquesas Islands).

Dorsal rays IX, 22 to 24 (except in the Hawaiian Islands where the soft rays range to 26); anal rays III, 19 to 22; pectoral rays 14 to 16; anterior gill rakers of eight specimens from the Marshall Islands 19 to 22; posterior gill rakers 20 to 24; anterior gill rakers of eight specimens from the Hawaiian Islands 18 to 22; posterior gill rakers 19 to 22; a 54 mm. specimen has 12 upper and 14 lower teeth; a 134 mm. specimen has 14 upper and 16 lower teeth; a 158 mm. specimen has 16 upper and 18 lower teeth.

Very rarely specimens were found with VIII dorsal spines, but these could be recognized as abnormalities. The specimen reported with VIII dorsal spines from Tahiti by Schultz and Woods (1948: 250), for example, has a broad gap between its seventh and eighth spines.

Color (in life) light olivaceous gray, shading to white ventrally, with six narrow vertical black bars on head and body, the first running through eye, the second from origin of dorsal fin to base of pectoral fin, and the last dorsally on caudal peduncle; fins olivaceous gray except for margins of anal and pelvic fins which are white. Often there is a sharp demarcation between the gray color of about the upper five-sixths of the body and the pure white lower sixth, and there may be a narrow irregular dark line dividing these two colors. Schultz and Woods (1948: 248) attribute this line and the abrupt transition to white to breeding coloration. I am unable to confirm this finding, for I have observed numerous specimens with the gonads only slightly developed which exhibit this color pattern.

It was noted that specimens of *A. triostegus* from coral atolls or low-lying coral islands had narrower vertical bars on the side of the body than specimens from high islands. In 20 specimens 110 mm. or more in standard length from low islands (10 of which were collected from Midway, Laysan, French Frigate Shoal, and Johnston Island) the width of the central bar of the body (as measured midlaterally) is contained 3.3 to 8.2 times

in the greatest diameter of the eye; the mean is 5.27. The width of the bar into the eye in 20 specimens of comparable size from high islands (including the Hawaiian Islands) is 1.7 to 3.9 with a mean of 2.65. Seven specimens from a tidal pond on the island of Hawaii were strongly melanistic, and the bar width was contained in the eye diameter 1.25 to 1.8 times with a mean of 1.43. The water in this pond was clear, and the bottom was black basalt with no coral and little algae. Around coral islands the bottom is notable for being light in color. The littoral area of volcanic islands is considerably darker, in general, due to the dark brown to black color of basalt. The above mentioned tidal pond on Hawaii is unusually dark. It is therefore believed that the width of the black bars of *A. triostegus* is correlated with the degree of darkness of the substrate. This is in agreement with the well-known phenomenon of increased production of melanophores from a dark background (Breder and Rasquin, 1952: 19).

Schultz and Woods (1953: pl. 64, A, B, C) have photographs of the postacronurus and juvenile stages of *A. triostegus*.

The 5.5 mm. postlarval specimen (Fig. 3) of *A. triostegus* was taken in a plankton tow with a 1 meter net offshore from the Hawaiian Islands by personnel of the Pacific Oceanic Fishery Investigations.

Streets (1877: 67) first called attention to the differences in color between *A. triostegus* in the Hawaiian Islands and elsewhere in its range; he designated the Hawaiian form as variety *sandvicensis*. It has an elongate black streak at the base of the pectoral fin, a vertical black bar dorsally on the caudal peduncle which reaches almost to the mid-lateral line but usually has no black spot on the peduncle below this bar; there is no definite black line mid-dorsally on the head. From the rest of its range specimens have a single black spot, two black spots, or a short bar at the pectoral base; the vertical black bar on the caudal peduncle is usually more restricted to the dorsal part and there is a black spot or short

bar ventrally on the peduncle; a median black line is usually evident on the head.

Schultz and Woods (1948: fig. 1) diagrammed the different color marks at the base of the pectoral fin of *A. triostegus* and tabulated the dorsal, anal, and pectoral fin ray counts of samples from a number of localities. They demonstrated the higher fin ray counts of the species in Hawaii; however they pointed out the possibility that cooler water in the Hawaiian Islands may be the cause of these higher counts. Nevertheless, these authors (and others) regarded the Hawaiian form as a full species, *Acanthurus sandvicensis*. In view of the marked geographical separation of the Hawaiian chain from other major island groups, at least slight differences are to be expected in Hawaiian populations of reef fishes. Since there is no possibility of readily testing whether Hawaiian stocks will freely interbreed with those of other areas, the task of making inferences of degree of interfertility from the observed morphological differences must be made. In my opinion the differences of *A. triostegus* in the Hawaiian Islands are not of sufficient magnitude to warrant their recognition as a basis of a species. Because of the frequent use of the name *sandvicensis*, however, I prefer to retain this as a subspecific designation for the species in Hawaii.

I have made dorsal and anal fin ray counts of *A. triostegus* from various localities (Table 2) in order to note variation from area to area and in the hope of shedding light on the question of whether water temperature has any effect on the number of fin rays. Unfortunately the number of specimens are too few in some important localities to be certain whether the apparent differences are real or due to chance. Other difficulties bear mentioning. Cooler temperatures, when correlated with high fin ray counts, might seem to be the cause of the high counts; however these might be a manifestation of the differentiation of populations in different areas. Unless counts are made from small juveniles from



such regions, the temperature at which the number of fin rays was fixed during development could not be estimated with any degree of assurance. Even more disturbing is the problem of fin ray counts made from specimens from colder areas in the path of currents from warm regions. If the counts were made from individuals of a resident population, they would reflect possible temperature effects of the area. If, however, the counts were made from fish carried as larvae from a warmer area, such an interpretation would be erroneous. The duration of the planktonic larval life of *A. triostegus* in the Hawaiian Islands has been estimated as two and one-half months (Randall, MS). Larvae of *A. triostegus* could float from the Philippines to Japan in about half this time (computed from current velocities given by Sverdrup, Johnson, and Fleming, 1946: 720). Therefore, the fin ray counts of specimens from S. Africa, New South Wales, Okinawa, and S. Japan are here not considered with respect to temperature effects on the number of fin rays.

Disregarding those areas in Table 2 in which a single specimen was available for fin ray counts, there remain eleven regions where average monthly sea surface temperatures (based on Hydrographic Office Pub. No. 225) may dip to 78° F. or lower at least one month of the year. These are Mauritius, Ningpo, China (the southerly current along the coast of China permits consideration of this locality but not Okinawa or S. Japan which are directly in the path of the Kuroshio), Marcus Island, Tahiti, Tuamotu Archipelago, Mangareva, possibly the Marquesas Islands, Galapagos Islands, Clarion Island, Hawaiian Archipelago, and Johnston Island. In seven of these regions (Mauritius, Marcus, and the Tuamotus excepted) the counts tend to be high; the number of specimens in the samples with 21 or more anal rays exceeds or is equal to the number with 20 rays. Four of these seven regions, Ningpo, Mangareva, Galapagos, and Clarion have a month in which the average sea surface temperature is 72° or

less. With the exception of Galapagos, these are all areas in which the samples display a definite increase in fin ray counts. Although more counts are needed from these and other colder areas and more precise information on temperature, the data suggest that cool water is correlated with high dorsal and anal fin ray counts of *A. triostegus*.

The fin ray counts of specimens of *A. triostegus* from the principal Hawaiian Islands (Kauai to Hawaii) seem higher than might be expected from the annual range of average monthly sea surface temperatures (normally about 75° to 82° F. as based on U. S. Coast and Geodetic Survey Pub. TW-2). The dorsal rays, for example, are apparently higher than those from specimens in any other region given in Table 2 except possibly Ningpo, China. Moreover, the counts of the dorsal and anal rays of specimens from Midway to French Frigate Shoal are not higher than the Hawaiian Islands proper in spite of lower temperatures in the Leeward group (about 70° to 80° F.). This suggests that the greater number of fin rays in the Hawaiian Archipelago may be due to genetic factors; the usual temperature variation within this chain of islands may not influence the number of rays. This is consistent with the color differences of the species in the Hawaiian Islands as given above. These color differences are probably genetically governed, for no specimens from colder areas other than the Hawaiian chain were seen with typical *sandvicensis* markings.

Fowler (1927b: 20) noted that there was a dark streak at the base of the pectoral fin of specimens from Fanning Island in the Line Islands. I examined two of his specimens at the Bishop Museum. One of these, 109 mm. in standard length, has a definite 10 mm. streak in which the eye diameter is contained 1.2 times. This is only about half the length of the usual *sandvicensis* streak, however.

Other slightly streaked specimens were found among the collections from the Line Islands and the Phoenix Islands (and to a lesser extent in some juveniles from Tahiti).

The most pronounced streaks, 1.25 to 1.5 eye diameters in length, were seen on five specimens, 41 to 61 mm. in standard length, from Enderbury Atoll. These specimens were from the sample from which the high fin ray counts recorded in Table 2 were made. These counts are the highest of all the samples from warm water regions in the table. The streaked specimens did not exhibit higher numbers of dorsal or anal rays than those with typical *triostegus* coloration. The same applies to other specimens with short streaks (or elongate spots) from the Phoenix and Line Islands.

The tendency to streaking at the base of the pectoral in island groups to the south of Hawaii might somehow be due to interbreeding effects from larvae carried to these areas from the Hawaiian Islands or Johnston Island. Admittedly this is difficult to explain in terms of existing current patterns because of the strong westerly component of the equatorial currents. Transport back to the east in the counterequatorial does not appear to provide the answer, for it would seem that larvae would be carried at least to the Marshall Islands before the counterequatorial could possibly be reached; thus one would expect to find any effects of interbreeding to be most pronounced in the Marshall Islands. This, however, is not the case.

The size of the transforming acronurus larva of *A. triostegus*, again suggests genetic influence of Hawaiian populations in islands to the south. The acronurus or late postlarval form of *A. triostegus* enters tide pools to transform to the juvenile stage. Due to the accessibility of tide pools for collecting and the abundance of the species, the transforming stage often appears in museum collections. Fifty-six such specimens from the East Indies, Palaus, Marianas, and Gilbert Islands, all very warm regions of the Pacific, range in standard length from 19 to 25 mm. and have a mean length of 21.7 mm. The 42 available specimens of the transforming acronurus stage were measured from the following cooler regions of the Pacific: Ningpo, Marcus Island,

TABLE 2  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus triostegus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS					ANAL SOFT RAYS			
	22	23	24	25	26	19	20	21	22
Natal, S. Africa . . . . .	2	6	1				6	3	
Mauritius . . . . .	7	9	2			2	11	5	
S. India . . . . .	1		1				2		
Siam . . . . .		1					1		
Maroubra Bay, New South Wales . . . . .	1	1	1				1	2	
East Indies and Philippines . . . . .	4	6				1	8	1	
Okinawa . . . . .		1	6	2			4	5	
Ningpo, China (29.5° N) . . . . .			3	9				7	5
S. Japan (30.4° N) . . . . .			3				2	1	
Palau Islands . . . . .	2	7	6				10	5	
Solomon Islands . . . . .	1	1					2		
Fiji Islands . . . . .		1					1		
Samoa Islands . . . . .	3	16	6			1	16	8	
Gilbert Islands . . . . .		9	22	2			3	19	11
Marshall Islands . . . . .	10	31	4				5	28	12
Wake Island . . . . .		3	14	2				12	7
Marcus Island . . . . .			3	1				4	
Mariana Islands . . . . .	2	19	4			2	18	5	
Cook Islands . . . . .		1					1		
Tubuai Islands . . . . .		1					1		
Tahiti . . . . .	1	12	8			1	10	10	
Tuamotu Archipelago . . . . .	1	9	1				7	4	
Mangareva . . . . .	1	2	2				2	1	2
Marquesas Islands . . . . .	1	8	5				6	8	
Phoenix Islands									
Hull and Canton . . . . .	6	35	11			1	38	13	
Enderbury . . . . .	1	7	7				3	10	2
Baker Island . . . . .	1	2				1	1	1	
Line Islands									
Palmyra . . . . .	6	28	7			4	28	9	
Fanning . . . . .		4	1				3	2	
Washington and Christmas . . . . .			6				6		
Galapagos Islands . . . . .	1	3					2	2	
Cocos Island (Costa Rica) . . . . .	2	6	1			2	5	2	
Clipperton Island . . . . .		1					1		
Clarion Island . . . . .	3	6	5			2	4	8	
Gulf of California . . . . .		1				1			
Hawaiian Archipelago									
Kauai to Hawaii . . . . .	1	36	59	5	1		15	72	15
Midway to French Frigate Shoal . . . . .	1	17	17				7	27	3
Johnston Island . . . . .		5	15	3			1	18	4

Tahiti, Tuamotu Archipelago, Mangareva, Marquesas, and Clarion Island. The standard length of these range from 22.5 to 26.5 mm. with a mean of 24.8 mm. The larger average size of the acronuri developing in cooler water



is probably a temperature effect. Seventy-seven transforming specimens from the Hawaiian Islands vary from 23 to 29.5 mm. in standard length, with a mean length of 25.9 mm. This is higher than one might expect if the average postlarval size were wholly dependent on temperature. Twenty-two specimens from the Phoenix Islands vary from 23 to 27 mm. and have a mean standard length of 24.9 mm. Only two specimens were found in collections from the Line Islands; these measured 23.5 and 24 mm. in standard length. The large size in the Phoenix Islands (and possibly also in the Line Islands) is not consistent with the sea surface temperatures of these groups (in excess of 80° F. throughout the year). These islands are no more geographically isolated than most of the other islands of the Pacific where the sea surface temperatures are warm, so there is no reason to suspect any marked population differentiation.

The largest specimen of adult *Acanthurus triostegus* examined by me was one of a series of 17 caught by personnel of the Pacific Oceanic Fishery Investigations with a beach seine at Midway Island. It measured 213 mm. in standard length. Twelve others in the sample ranged from 174 to 206 mm. in standard length. Of over 5,000 adult specimens caught in traps off Oahu, the longest was 175 mm. in standard length. The colder water at Midway may be the principal basis for the larger size at this locality. In a small collection from Clarion and Socorro in the Revillagigedo Islands (Mexico) there are two large specimens measuring 187 and 188 mm. in standard length. The water around these islands is also cool. Of 905 specimens reported by Schultz and Woods (1953: 624) from the Marshall Islands and Marianas, the largest was 152 mm. The species appears to be small in other warm areas of the Pacific except the Line Islands and the Phoenix Islands where specimens as large as 189 mm. in standard length have been taken.

The range of *Acanthurus triostegus*, as is apparent from the above discussion, is very

extensive. This species is in continuous distribution from East Africa to the tropical Pacific; it is one of the three species of the genus *Acanthurus* to have crossed the eastern Pacific barrier. It is recorded from the Galapagos Islands, Cocos Island off Costa Rica, and Clipperton Island, the Revillagigedo Islands, and Tres Marias Islands off the coast of Mexico. Vernon E. Brock has informed me that the species is rare at islands off the coast of Mexico. Boyd W. Walker kindly loaned a 94 mm. specimen collected by M. A. Newman and J. E. Fitch from Frailes Bay, Gulf of California. This is the first record from the coast of North America.

There is one record of *A. triostegus* from the Atlantic Ocean, that of Steindachner (1882: 54) from the Congo coast of Africa. Further records are needed to substantiate this.

Schultz and Woods (1948: 250) observed a much higher incidence of specimens of *A. triostegus* with two spots at the base of the pectoral fin than with a single spot or bar in the Marquesas Islands; these authors proposed the subspecific name *marquesensis* for the species in this group of islands.

It is interesting to note that neither this nor the Hawaiian subspecies has reached the coast and continental islands of America. Instead, the eastern Pacific form is *A. triostegus triostegus* which is found in the Line Islands and elsewhere in Oceania (except Hawaii and the Marquesas). This supports the contention of Herre (1940) that the counterequatorial current would seem to be the only possible mode of transport of Indo-West-Pacific fishes to the American coast. Jordan and Seale (1906: 354), Herre (1927: 409), and de Beaufort (1951: 147) are probably all in error in stating that the *sandvicensis* form of the species occurs at islands offshore from Mexico. All of the specimens which I have seen from such islands have a single black spot at the pectoral base, or occasionally two spots, or a short bar.

De Beaufort (1951: 147) stated that the typical form of *Acanthurus triostegus* occurs together with the subspecies *sandvicensis* in

the Hawaiian Islands. The basis for his statement is probably the information from Fowler (1928: 265) to the effect that the brown band in some specimens of the *sandvicensis* form does not continue below the pectoral base. I have never seen a specimen of *A. triostegus* from the Hawaiian Islands on which the brown streak does not continue below the base of the pectoral fin. Considerable variability may be observed in this marking, however, and it is conceivable that very rarely a specimen might be found with only a short bar at the pectoral base. Often the streak is interrupted such that a short bar at the pectoral base is separated from the larger part of the streak below. The streak may even be broken into three separate segments.

***Acanthurus polyzona* (Bleeker)**

Fig. 5

*Rhombotides polyzona* Bleeker (1868a: 277) (Réunion); Bleeker in Bleeker and Pollen (1874: 44, pl. 12, fig. 2).

*Acanthurus triostegus* var. *polyzona* Peters (1876: 439).

*Acanthurus polyzona* Sauvage (1891: 519).

Dorsal rays IX, 23 to 25; anal rays III, 21 to 23; pectoral rays 16; eight or nine teeth on each side of upper jaw and nine or ten on each side of lower jaw.

Bleeker described the color in life as olivaceous on the back and olivaceous-silvery ventrally, with vertical black bars as follows: the first rostro-frontal on head (not very evident in figure), the second maxillo-ocular, the third oculo-interopercular, the fourth opercular, the next six on the body proper, and the last two on the caudal peduncle.

This species seems to be closely allied to *A. triostegus*, sharing with it the slightly emarginate caudal fin, low number of dorsal and anal fin rays, small caudal peduncle spine (as based on the figure in Bleeker and Pollen)

and barred color pattern. Unlike the bars of *A. triostegus*, those of *A. polyzona* are more numerous and much broader dorsally than ventrally.

*Acanthurus polyzona* is apparently known only from the island of Réunion in the Indian Ocean. I have seen no specimens of this species.

***Acanthurus nubilus* (Fowler and Bean)**

Figs. 2b, 6

*Hepatus (Harpurina) nubilus* Fowler and Bean (1929: 253, fig. 15) (Dodepo Island, Celebes).

*Harpurina nubilus* de Beaufort (1951: 166, fig. 27).

Dorsal rays VI, 27; anal rays III, 24; pectoral rays 16; anterior gill rakers 21; posterior gill rakers 24; 24 upper teeth; 28 lower teeth. These counts are based on the holotype, 153 mm. in standard length. Other specimens of this species reported on by Fowler and Bean were not located. These authors recorded the number of dorsal spines as VI or VII.

Mouth small, its width as measured from rictus to rictus contained 3.8 times in head



FIG. 5. *Acanthurus polyzona* (after Bleeker and Pollen, 1874).



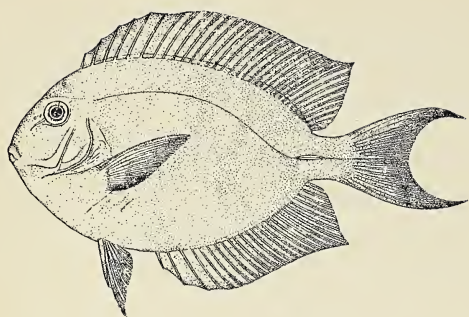


FIG. 6. *Acanthurus nubilus* (after Fowler and Bean, 1929).

length; snout short, snout length 6.8 in standard length; depth of body 1.8 in standard length; head length 4.1 in standard length; least depth of caudal peduncle 1.8 in head length; diameter of eye 3 in head length; caudal concavity 6.7 in standard length.

Color given by Fowler and Bean, for specimens other than the type, is as follows: "Nearly black, shading to brown under scales, probably dark seal brown with slaty streaks in life, of which usually 2 to each scale row. On side of head and breast brown in form of hexagonal spots in pale ground color, spots size of number 6 shot. No black shoulder blotch or black spots in axils of verticals. Fins nearly black. Dorsal with oblique bars extending upward and backward, best seen in reflected light. Oblique bars very indistinct on anal. Caudal without markings. Pectoral membranes hyaline."

Color (in alcohol) of holotype uniformly brown except membranes of pectoral fin which are hyaline.

This species is known only from Buka Buka Island in the Gulf of Tomini, Celebes, and Dodepo Island, Celebes.

*A. nubilus* is related to *A. thompsoni* and *A. bleekeri*. These three species of *Acanthurus* are distinctive in having small mouths, small teeth, and a moderately large eye which is set more toward the center of the head than other species in the genus.

Were it not for *A. thompsoni* and *A. bleekeri*, *A. nubilus* would probably best be placed by itself in the genus *Harpurina* because of the above characteristics and its VI or VII dorsal spines. The former species possess the usual IX dorsal spines and serve to connect *A. nubilus* with more typical *Acanthurus*.

### *Acanthurus bleekeri* Günther

Figs. 2c, 7

*Acanthurus mata*. Bleeker (non Cuvier and Valenciennes) (1854b: 432) (Java); Aoyagi (1943: 206, pl. 4, fig. 9, teeth only).

*Acanthurus bleekeri* Günther (1861: 335) (after Bleeker); Herre (1927: 423, pl. 14, fig. 2) (Philippine Islands); de Beaufort (1951: 162) (East Indies); Schultz and Woods in Schultz *et al.* (1953: 636) (Rongelap Atoll, Marshall Islands).

*Rhombotides Bleekeri* Bleeker (1863a: 153) (Halmahera, East Indies).

*Acanthurus Bleekeri* Klunzinger (1871: 509) (Red Sea).

*Acanthurus aurolineatus* Day (1876: 204, pl. 48, fig. 3) (Coromandel coast of India); Day (1889: 139).

*Acanthurus (Rhombotides) Bleekeri* Klunzinger (1884: 85) (Red Sea).

*Harpurus gnophodes* Fowler (1904: 544, pl. 22, upper fig.) (Padang, Sumatra).

*Teuthis mata*. Kendall and Goldsborough (1911: 310) (Tuamotu Archipelago).

*Acanthurus Güntheri* Weber (1913: 317) (Ambon, East Indies).

*Hepatus weberi* Ahl (1923: 317) (new name for *Acanthurus Güntheri* Weber).

*Hepatus bleekeri* Fowler (1928: 270) (Sumatra and Fakarava, Tuamotu Archipelago); Fowler and Bean (1929: 220) (Philippine Islands and East Indies); Hiyama (1943: 94, pl. 19, fig. 54).

*Teuthis bleekeri* Fowler (1949: 102).

*Acanthurus weberi* de Beaufort (1951: 163) (East Indies).

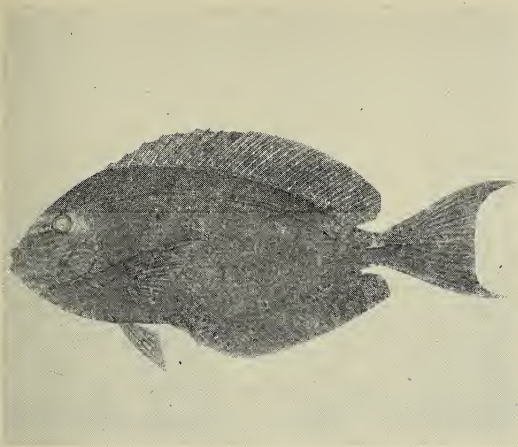


FIG. 7. *Acanthurus bleekeri* (after Hiyama, 1943).

Dorsal rays IX, 24 to 26; anal rays III, 23 or 24; pectoral rays 16 or 17; (usually 17); anterior gill rakers 13 to 15 and posterior gill rakers 13 to 15 (gill raker counts from Philippine specimens); a 71 mm. specimen has 14 upper and 16 lower teeth; a 146 mm. specimen has 18 upper and 22 lower teeth; a 200 mm. specimen has 22 upper and 24 lower teeth; a 283 mm. specimen has 24 upper and 26 lower teeth.

TABLE 3  
VARIATION IN FIN RAY COUNTS OF SPECIMENS  
OF *Acanthurus bleekeri* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS	
	24	25	26	23	24
Delagoa Bay, S. Africa.....		1			1
East Indies.....		4			4
Philippine Islands.....	2	5	4	2	9
Tuamotu Archipelago.		1			1
Marshall Islands.....			1		1

Mouth small, its width from rictus to rictus contained 4.7 to 5 in head length; snout short, its length 6.6 to 6.9 in standard length; relative body depth decreasing with size from 2.1 in standard length in 118 mm. specimen to 2.5

in 283 mm. specimen; forehead sloping, the angle between a vertical at the mouth and the anterior profile of the head about 45°; length of head 3.6 to 3.7 in standard length; diameter of eye 3.2 to 4.5 in head length in specimens over a range in standard length of 118 to 283 mm.; caudal concavity about 6.5 to 8 in standard length (9 in a 71 mm. specimen); least depth of caudal peduncle 10 to 12 in standard length. This species has a narrower caudal peduncle than all other species of *Acanthurus* (in which the least depth is contained 7.7 to 9.5 times in the standard length). The stomach is large, U-shaped, with about nine rows of very large, thorn-like papillae on the inner surface.

Color (in alcohol) brown with fairly straight lengthwise pale bluish gray lines on the side of the body (28 in a specimen 200 mm. in standard length, each line about one-third as broad as the brown interspaces); head with similar, though slightly more irregular, lines (eight between eye and lower limb of preopercle in the 200 mm. specimen); opercular membranes dark brown; sheath of caudal spine blackish brown and edge of socket dark brown; all fins brown, the dorsal with a dark brown line at the base which becomes broader posteriorly, and the dorsal and the anal with faint longitudinal banding.

Life colors from Hiyama's plate (herein reproduced in black and white as Fig. 7) dark brown with lengthwise blue lines on head and body, a yellow area behind eye, and two yellow bands extending anterior from eye, one from the upper edge and one from the lower.

J. L. B. Smith kindly loaned a specimen identified in his *The sea fishes of southern Africa* (1949: 240, pl. 33, no. 609) as *Acanthurus lineolatus*. The specimen is 71 mm. in standard length and was collected in Delagoa Bay. The species figured by Smith appears to be *A. mata*, however, the specimen turned out to be *A. bleekeri*, hitherto unrecorded from southern Africa. It has been returned to Dr. Smith.



*Acanthurus bleekeri* is an Indo-West-Pacific species. It is not recorded from the Hawaiian Islands and is not commonly taken from the rest of the tropical Pacific.

### *Acanthurus thompsoni* (Fowler)

Figs. 2d, 8

*Hepatus thompsoni* Fowler (1923: 386) (Honolulu); Fowler and Ball (1925: 19) (Wake Island); Fowler (1928: 268, fig. 49); Fowler (1938: 231) (Honolulu).

*Acanthurus philippinus* Herre (1927: 434, pl. 5, fig. 1) (Calapan, Mindoro, Philippine Islands); Schultz and Woods *in* Schultz *et al.* (1953: 637) (Rongelap, Marshall Islands); de Beaufort (1951: 161).

*Hepatus philippinus* Fowler and Bean (1929: 215, fig. 11) (Philippine Islands and East Indies); Kamohara (1952: 8) (Okinoshima, Province of Tosa, Japan).

*Teuthis thompsoni* Fowler (1949: 102).

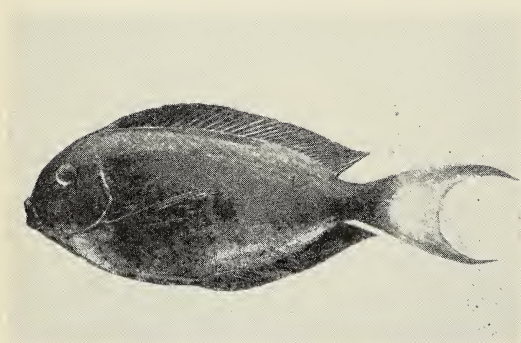


FIG. 8. *Acanthurus thompsoni*. 138 mm. specimen, Gilbert Islands. From a Kodachrome transparency by the author.

Dorsal rays IX, 23 to 26; anal rays III, 23 to 26; pectoral rays 17; anterior gill rakers of two Philippine and one Marshall Islands specimens 15 to 16; posterior gill rakers 14 to 15; anterior gill rakers of one Hawaiian Islands specimen 18; posterior gill rakers 16; a 93 mm. specimen has 20 upper and 24 lower teeth; a 138 mm. specimen has 21 lower and 24 upper teeth.

TABLE 4

VARIATION IN FIN RAY COUNTS OF SPECIMENS OF *Acanthurus thompsoni* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS			
	23	24	25	26	23	24	25	26
East Indies.....		1		1		1		1
Philippine Islands..	2	2	1		1	3	1	
Marshall Islands...			1				1	
Gilbert Islands:...			1			1		
Society Islands...			1		1			
Hawaiian Islands..		1		2		2		1

Mouth small, its width from rictus to rictus contained about 4 times in head length; snout very short, its length 7.9 to 8.2 in standard length; body depth about 2.3 in standard length; head length 3.7 to 4.3 in standard length; diameter of eye 3.2 to 3.5 in head length in specimens over 90 mm.; least depth of caudal peduncle 2.2 to 2.5 in head length; caudal concavity about 5 in standard length.

Color (in alcohol) brown with pale yellowish brown caudal fin (except specimens from the Hawaiian Islands in which the caudal fin is as dark as the body); a small dark brown spot just below and adjacent to axil of pectoral fin (this spot not as prominent as Fowler figured it and is difficult to see in dark specimens); about six dark bands may be visible running lengthwise in posterior part of soft dorsal fin and about five in the anal fin, although in many specimens these have faded.

Herre (1927: 434) stated that the pale caudal fin of his Philippine specimens was evidently yellow in life; however, the single specimen which I collected in the Gilbert Islands had a snow white caudal fin (which became dusky white immediately following death).

A 134 mm. specimen speared by me at a depth of 90 feet in Kealakekua Bay, Hawaii, was olive drab with brown fins; the dorsal and anal fins had a narrow blue-black margin,

and there were two to three narrow longitudinal yellow-brown lines in the outer part of these fins; the pelvic fins showed brownish yellow patches distally; the head had a reticulation of purplish yellow and brownish yellow lines. A 49 mm. juvenile specimen (U.S.N.M. No. 167250) was taken in the same locality and at the same depth. It was apparent from the scale structure and the dentition that it had only recently transformed from the acronurus stage. It was purplish blue with black longitudinal lines on the side of the body; the pectoral was yellowish with a black line at the top; there was a small black spot at the axil of the dorsal fin; however none was visible at the lower part of the axil of the pectoral fin.

I examined the holotype (Bernice P. Bishop Mus. No. 3394) and compared it with the specimen from the Gilbert Islands. Apart from the color of the caudal fin, no differences could be observed.

The largest specimen seen by me is the holotype. It is 155 mm. in standard length.

Schultz and Woods (1953: 637) stated that the species was observed swimming in a large school in the Rongelap lagoon about coral heads at depths of more than 10 feet. I saw only two solitary individuals at Onotoa Atoll in the Gilbert Islands; these occurred at a

depth of from 40 to 50 feet on the coralliferous terrace of the outer reef. The adult which was collected in Hawaii was one of a group of about eight or ten individuals that tended to stay in the same general region of the reef. They were seen several times swimming slowly, about 10 to 20 feet off the coral-covered bottom. Upon my approach they swam almost straight down. Underwater some appeared dark gray, almost black, and others were light blue.

*Acanthurus thompsoni* occurs in the East Indies, Philippines, Japan, and Oceania. In general, it is not a common species.

### *Acanthurus mindorensis* Herre

Fig. 9

*Acanthurus mindorensis* Herre (1927: 433, pl. 4, fig. 2) (Cālapān, Mindoro, Philippine Islands).

*Hepatus mindorensis* Fowler and Bean (1929: 213).

The following is from Herre's description: dorsal rays IX, 26; anal rays III, 23; origin of mouth low on head; jaws protuberant; length of snout 1.25 in length of head (taken from figure); length of head 3.4 in total length; depth at origin of pelvics 2.3 in length; eye 4.16 in head length; interorbital gently rounded, 2.94 in head and nearly thrice eye (one of the last two proportional measurements, probably the latter, is an error); caudal spine slender, its length equal to diameter of eye; depth of caudal peduncle 2.77 in head; caudal fin moderately concave, caudal concavity 11 in standard length (from figure); pectoral fin 1.16 in head; pelvic fin 0.1 as long as head. The type, a 170 mm. specimen, had eight broad denticulate teeth on each side of the upper jaw and eight or nine on each side of the lower jaw. The denticulations on the lower teeth were more confined to the ends of these teeth than were those on the upper teeth. The color (in alcohol) was black,

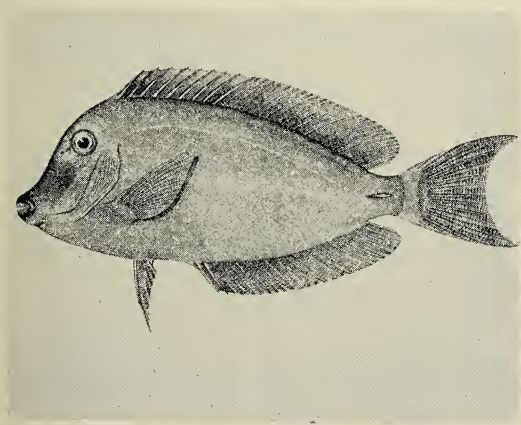


FIG. 9. *Acanthurus mindorensis* (after Herre, 1927).



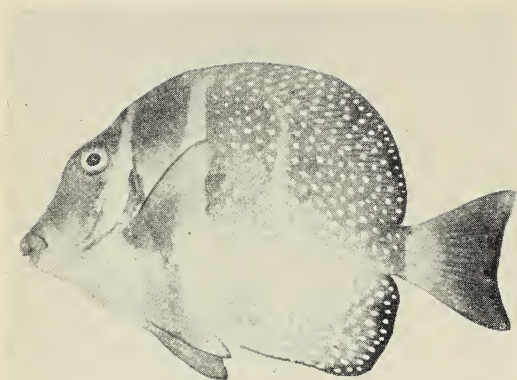


FIG. 10. *Acanthurus guttatus*. 118 mm. specimen, Gilbert Islands. From a Kodachrome transparency by the author.

sides of head and breast blackish brown; a deep brown ring at base of caudal; all fins black.

Herre has informed me that the type of this species was destroyed in Manila during World War II. To my knowledge there are no other specimens in existence.

There are two important differences between Herre's description and his figure, and at the present time there is no way to reconcile these. He described the species as having IX dorsal spines, the first one longer than in most species and not concealed. The figure shows X dorsal spines, the first smaller than that as seen on most of his figures of other species of *Acanthurus*. The deep brown ring at the base of the caudal fin is not apparent in the figure. Instead the base of the caudal fin has a pale band.

The most distinctive feature of this species is the peculiar shape of the head.

***Acanthurus guttatus* Bloch and Schneider**  
Figs. 1j, 2e, 10

*Acanthurus Guttatus* Bloch and Schneider (1801: xxxviii, 215) (Tahiti).

*Acanthurus guttatus* Cuvier and Valenciennes (1835: 195) (Tonga Islands and Mauritius);

Günther (1861: 329) (Tahiti, New Hebrides, and Mauritius); Günther (1873: 109, pl. 69, fig. A) (Indo-Pacific); Waite (1897: 188) (Funafuti, Ellice Islands); Jordan and Jordan (1922: 66) (Hawaiian Islands); Schultz (1943: 163) (Phoenix and Samoa Islands); de Beaufort (1951: 142) (Sumatra); Schultz and Woods in Schultz *et al.* (1953: 631, pl. 66, fig. A) (Marshall and Mariana Islands); Harry (1953: 146) (Rarua, Tuamotu Archipelago).

*Harpurus guttatus* Forster (1844: 218) (Tahiti).

*Rhombotides guttatus* Bleeker in Bleeker and Pollen (1874: 96) (Réunion and Mauritius).

*Zabラスoma guttatus* Seale (1901: 110) (Guam).

*Teuthis guttatus* Jenkins (1903: 479) (Honolulu); Kendall and Goldsborough (1911: 310) (Gilbert Islands and Tuamotu Archipelago); Fowler (1949: 103) (Baker Island).

*Hepatus guttatus* Jordan and Evermann (1905: 392, fig. 70) (Honolulu); Jordan and Seale (1906: 354) (Samoa); Fowler and Bean (1929: 248) (Philippine Islands, Samoa, Gilbert Islands, and Mauritius); Fowler (1938: 184) (Tongareva).

*Teuthis fuliginosus*. Whitley and Colefax (1938: 294, pl. 14, fig. 4) (Nauru Island).

Dorsal rays IX, 27 to 30; anal rays III, 23 to 26; pectoral rays 15 to 17; anterior gill rakers 21 to 24; posterior gill rakers 19 to 23 (gill raker counts based on specimens from Samoa); a 43 mm. specimen has eight upper and eight lower teeth; an 85 mm. specimen has ten upper and ten lower teeth; a 152 mm. specimen has 12 upper and 12 lower teeth; a 187 mm. specimen has 12 upper and 14 lower teeth.

Body depth great, 1.5 to 1.6 in standard length; caudal fin slightly emarginate, caudal concavity contained about 14 to 17 times in standard length. Length of pectoral fin about 2.7 in standard length.

Color (in alcohol) brown with many small round or elliptical white spots (usually bordered with dark brown) on posterior half of body and dorsal and anal fins, and three ver-

tical white bars, the first on head just behind eye, the second running from base of fourth dorsal spine to anus, and the third (about one-third as broad) from base of fifth or sixth dorsal soft rays to the second or third anal soft rays; pectoral dusky yellow; pelvics light brown; caudal fin with basal half light brown, outer portion brown.

In life the pelvic fins are bright yellow. *Acanthurus guttatus* is characteristic of turbulent water in shallow reef areas. In atolls it is commonly found schooling in surge channels.

The postacronurus may appear in tide pools. Three such specimens (Fig. 1*j*) vary in standard length from 33 to 36 mm. The largest adult specimen seen by me was 228 mm. in standard length from the Hawaiian Islands.

De Beaufort (1951: 137) is probably in error in considering *Teuthis fuliginosus* Whitley and Colefax a synonym of *Acanthurus fuscus* Steindachner (the latter being a synonym of *Acanthurus pyroferus* Kittlitz). The specimen in Whitley and Colefax's photograph appears to be *A. guttatus* with the white spots barely visible.

*Acanthurus guttatus* would seem to stand

TABLE 5  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus guttatus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS			
	27	28	29	30	23	24	25	26
Mauritius.....	1	1			1	1		
Mariana Islands...		2	1	1		2	1	1
Wake Island.....	2	7	2			7	4	
Marshall Islands...	4	11	4		3	8	8	
Gilbert Islands....	2	2				2	2	
Samoa Islands....	1	7	4	1	2	7	3	1
Phoenix Islands...		1				1		
Society Islands....	2	3	2		1	2	4	
Tuamotu Archipelago....		1	1				1	1
Line Islands.....	1	1			2			
Hawaiian Islands..	1	3		1	1	2	2	

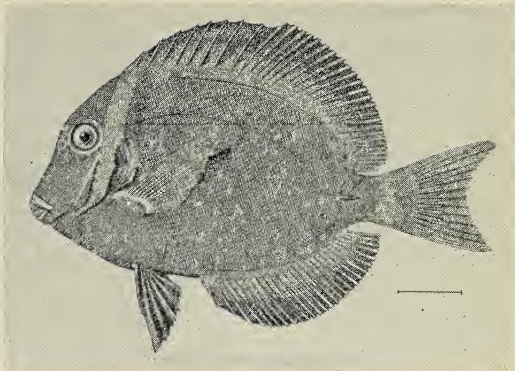


FIG. 11. *Acanthurus leucopareius* (after Jordan and Evermann, 1905).

apart from all other species of the genus primarily because of its deep body, nearly truncate caudal fin, and color pattern. *A. leucopareius*, however, appears to link this species with *A. nigrofuscus* and *A. nigroris*, for it is intermediate in body depth, caudal concavity, structure of the teeth, dorsal and anal fin ray counts, size, and color.

***Acanthurus leucopareius* (Jenkins)**  
Figs. 2*f*, 11

- Teuthis leucopareius* Jenkins (1903: 476, fig. 23) (Honolulu).  
*Teuthis umbra* Jenkins (1903: 477) (Honolulu); Kendall and Radcliffe (1912: 144) (Cook Bay, Easter Island).  
*Teuthis bishopi* Bryan and Herre (1903: 134) (Marcus Island).  
*Hepatus leucopareius* Jordan and Evermann (1905: 386, fig. 167) (Hawaiian Islands); Jordan and Seale (1906: 352); Fowler (1928: 266, pl. 30, fig. B) (Hawaiian Islands, Easter Island, and Marcus Island); Fowler and Bean (in part) (1929: 214) (Hawaiian Islands and Easter Island).  
*Hepatus umbra* Jordan and Evermann (1905: 387, pl. 47) (Honolulu); Jordan and Seale (1906: 353).  
*Acanthurus leucopareius* Jordan and Jordan (1922: 65) (Honolulu).  
*Acanthurus umbra* Jordan and Jordan (in part) (1922: 65) (Hawaiian Islands).



Dorsal rays IX, 25 to 27; anal rays III, 23 to 25; pectoral rays 16; anterior gill rakers 15 to 18; posterior gill rakers 18 to 21 (raker counts from Hawaiian specimens); a 38 mm. specimen has 8 upper and 10 lower teeth; a 70 mm. specimen has 10 upper and 12 lower teeth; a 109 mm. specimen has 12 upper and 14 lower teeth; a 145 mm. specimen has 14 upper and 16 lower teeth; a 197 mm. specimen has 16 upper and 20 lower teeth.

TABLE 6  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus leucopareius* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	25	26	27	23	24	25
Hawaiian Islands . . . .	6	15	2	3	16	4
Easter Island . . . . .	1			1		
Marcus Island . . . . .			1			1

Body depth 1.7 to 1.85 in standard length; caudal concavity 10 to 11 in standard length; length of pectoral fin 2.8 to 3.2 in standard length.

Color (in alcohol) brown with a dusky white band extending from origin of dorsal fin to posterior portion of opercle; posterior and adjacent to this white band a prominent dark brown band; anterior and adjacent to white band an obscure dark brown band which passes through eye; a small black spot at axil of dorsal fin (relatively large in Easter Island specimen); base of caudal fin with a distinct white band; all fins brown except pectorals which are pale with a narrow black upper margin; a faint longitudinal banding may be visible in dorsal and anal fins.

In some specimens the dark and light bands on the head are difficult to see. This is true of some freshly preserved specimens; therefore the lack of bands cannot be attributed solely to fading.

In life the white band on the head and the one at the base of the caudal fin are vivid. Faint irregular bluish lines may be seen on the body. In a 70 mm. specimen the bluish lines are fewer in number and more evident than in large specimens. On the upper one-third of the body they consist of oblique rows of discrete spots.

Transformation from the acronurus to the juvenile stage occurs at a size of about 33 to 34 mm. in standard length. The dark and light bands on the head are just making their appearance on a 40 mm. specimen.

I examined the type of *Teuthis bishopi* Bryan and Herre at the Bishop Museum (a 206 mm. specimen from Marcus Island) and the type of *Teuthis umbra* Jenkins at the United States National Museum; both are specimens of *Acanthurus leucopareius*. As the bands on the head of the type of *umbra* are very faint, it is understandable how Jenkins could have overlooked them and considered the specimen as representing a new species.

Since Jenkins, a number of authors have applied the name *umbra* to various species of *Acanthurus*. Of the specimens considered as *Acanthurus umbra* by Jordan and Jordan (1922), for example, some were *A. mata*, one was *A. xanthopterus*, and one was *A. leucopareius*. *A. mata* received the designation of *umbra* more than other species probably because of its marked pale band at the base of the caudal fin and lack of other obvious color markings.

Fowler (1928: 266) listed two "Albatross" specimens from Puako Bay, Hawaii (U.S.N.M. No. 55582) as *Hepatus leucopareius*. One of these, however, is either *Acanthurus xanthopterus* or *A. mata*. The two which he recorded as *leucopareius* from Apia, Samoa (U.S.N.M. No. 52456) are *Acanthurus nigroris*, as is the one from the Tubuai Islands (Bishop Mus. No. 750). The 105 mm. specimen from Suva, Fiji (Bishop Mus. No. 4339), which was identified as *Hepatus leucopareius*, is *Acanthurus mata*. Also misidentified by Fowler as *leucopareius* are two subadults from the New

Hebrides (Bishop Mus. No. 1028). Two specimens from Guam (Bishop Mus. No. 4261) which Fowler (1925: 12) reported as *Hepatus leucopareius* are 26 mm. acronuri which are definitely not this species.

Fowler (1930: 612) recorded *Hepatus leucopareius* from Hong Kong. I was unable to locate his specimen at the Academy of Natural Sciences of Philadelphia. Also I have not examined his specimens of *leucopareius* from the Philippines. His reference to their poor condition (1927a: 287) suggests that this may be a tenuous identification. A. W. Herre has written me that he has never seen *Acanthurus leucopareius* in the Philippines. The presence of the species in his checklist (1953: 536) is probably based on Fowler.

The only definite records of this species are from the Hawaiian Islands, Marcus Island, and Easter Island, all remote and widely separated areas of Oceania. If these three regions represent the total distribution, *A. leucopareius* would seem to be a relict species. It is easier to suppose that it was once in continuous distribution throughout Oceania but survives now only in these three outposts than to assume that it is endemic to one of these islands and spread to the others without becoming established in intervening areas.

This species is one of the most common of the genus in the Hawaiian Islands. It is most often seen in relatively shallow reef areas subject to some turbulence from wave action. It has been observed in schools.

### *Acanthurus nigroris* Cuvier

and Valenciennes

Figs. 1i, 2g, 12

*Acanthurus nigroris* Cuvier and Valenciennes (1835: 208) (Hawaii); Weber (1913: 317) (East Indies).

*Acanthurus lineolatus*. Bleeker (1854a: 101) (Banda Islands, East Indies); Günther (1873: 112, pl. 73, fig. A) (Society Islands); Steindachner (1901: 493) (Honolulu); de Beaufort (in part ?) (1951: 160) (East Indies).

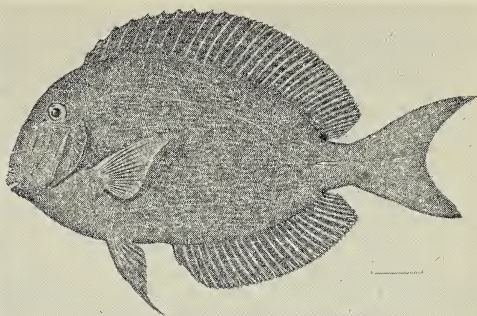


FIG. 12. *Acanthurus nigroris* (after Jordan and Evermann, 1905, retouched).

*Acanthurus bipunctatus* Günther (1861: 331) (China).

*Acanthurus nigros* Günther (1861: 332) (New Hebrides); Günther (in part) (1873: 110) (New Hebrides, Palau Islands, and Tahiti).

*Rhombotides lineolatus*. Bleeker (1865: 288) (Ambon, East Indies).

*Teuthis atrimentatus* Jordan and Evermann (1903: 198) (Honolulu); Jenkins (1903: 478) (Hawaiian Islands).

*Teuthis striatus*. Bryan and Herre (1903: 133) (Marcus Island).

*Hepatus atramentatus* Jordan and Evermann (1905: 393, fig. 171) (Hawaiian Islands); Jordan and Seale (1906: 352) (Samoa).

*Acanthurus atramentatus* Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1927: 422, pl. 3, fig. 1) (Philippine Islands).

*Hepatus elongatus*. Fowler (in part) (1928: 267) (Oceania).

*Hepatus lineolatus*. Fowler (in part) (1928: 270) (Oceania); Fowler and Bean (in part) (1929: 228) (Philippine Islands and Hawaiian Islands); Fowler (1931: 345) (Honolulu); Fowler (1938: 232) (Honolulu).

*Hepatus fuliginosus*. Fowler and Bean (in part) (1929: 211) (Honolulu).

*Hepatus leucopareius*. Fowler and Bean (in part) (1929: 214) (Apia, Samoa).

*Teuthis lineolatus*. Fowler (1941: 257, fig. 9) (Honolulu); Fowler (1949: 103) (Howland Island).

*Acanthurus elongatus*. Schultz (in part) (1943:



165) (Phoenix and Samoa Islands); Schultz and Woods in Schultz *et al.* (in part) (1953: 634, pl. 62, fig. C) (Marshall and Mariana Islands).

Dorsal rays IX, 23 to 27; anal rays III, 22 to 25 (one specimen from the Hawaiian Islands has IV anal spines); pectoral rays 15 or 16; a 61 mm. specimen has 10 upper and 12 lower teeth; a 96 mm. specimen has 12 upper and 14 lower teeth; a 159 mm. specimen has 12 upper and 14 lower teeth. See Table 9 for gill raker counts.

TABLE 7  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus nigroris* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS					ANAL SOFT RAYS			
	23	24	25	26	27	22	23	24	25
Marshall Islands.....	21	18				13	19	7	
Gilbert Islands.....	2	1				2	1		
Rose Island, Samoa Is.....	4	7					8	3	
Swains Island, Samoa Is....	1	3	3			2	5		
Phoenix Islands.....	2	12	7	1		3	17	2	
Line Islands.....	1	2				1	2		
Wake Island.....	4	7	1			10	2		
Oahu and Hawaii.....	1	7	20	2		4	14	12	
Laysan and French									
Frigate Shoal.....			2	6		1	3	4	
Johnston Island.....	3	8	9			1	6	10	3

Caudal concavity 5.8 to 10.5 in standard length (5.8 to 7.5 in specimens from the Hawaiian Islands and Johnston Island and 6.7 to 10.5 from elsewhere in the Pacific); body depth 1.8 to 2 in standard length; ends of central upper teeth rounded (Fig. 2g).

The largest specimen seen by me measures 204 mm. in standard length. It was collected at French Frigate Shoal.

Color (in alcohol) of Hawaiian specimens brown with irregular, lengthwise, bluish gray or dark brown lines (about one-fourth as broad as intervening brown areas) on body; about six or seven slightly irregular, narrow, dark bluish gray or dark brown lines on head

running parallel to profile of snout (in some preserved specimens these lines and those on the body are very faint or imperceptible); a small black spot about the size of the pupil at the axil of both the dorsal and the anal fins; dorsal fin with about five or six lengthwise dark brown bands; anal fin with four or five similar bands; a light grayish brown band often present at base of caudal fin; posterior margin of caudal fin very narrowly pale; pectoral fin pale with narrow dark upper margin; pelvic fins brown; no narrow black margin around socket of caudal spine.

In life the bluish gray or dark brown lines on the body and head are light blue; the dark bands in the dorsal and anal fins are bluish and the intervening bands light yellowish brown; pectoral fin rays dull yellow, membranes clear; iris yellow.

Wake Island specimens, even large adults, have rows of small round blue spots on the body instead of entire or slightly broken blue lines. Specimens from elsewhere in Oceania appear to be colored much like Hawaiian examples, as indicated in the color plate in Günther (1873) of a specimen from the Society Islands (identified as *Acanthurus lineolatus*).

The number of blue lines on the body are fewer in smaller specimens. A 51 mm. juvenile from the Hawaiian Islands, for example, has only 11 lines on the body.

In this species and *Acanthurus nigrofasciatus* the black spot in the axil of the dorsal fin makes its appearance before the spot in the axil of the anal fin. The dorsal spot first shows before these species complete the transformation from the acronurus to the juvenile state (which occurs at a standard length of from about 34 to 39 mm. in *A. nigroris*). The anal spot first appears on specimens of *nigroris* about 42 to 50 mm. in standard length.

*A. nigrofasciatus* seems to be closely related to *A. nigroris*, and these two species have often been confused. As indicated in the key, they may be separated by caudal concavity, body depth, maximum size, shape of upper teeth,

size of the spot in the axil of the dorsal fin, width of the pale posterior margin of the caudal fin, presence or absence of spots on the head, and presence or absence of a dark margin around the groove of the caudal spine. In addition, the posterior tips of the dorsal and anal fins of *A. nigrofuscus* are more pointed when these fins are elevated than are the fins of *A. nigroris*. The base of the caudal fin of *A. nigrofuscus* is rarely paler than the rest of the fin or the body. The bands in the dorsal and anal fins of *A. nigrofuscus* are poorly defined and rarely persist in preserved specimens. The lips of *A. nigrofuscus* tend to be blackish while those of *A. nigroris* are usually only slightly darker than the rest of the head.

Small juveniles of these two species are difficult to distinguish, but the greater concavity of the caudal fin and larger black spot at the base of the last few dorsal and anal rays of *A. nigrofuscus* still permit separation. I am unable, however, to distinguish with assurance the acronurus or postacronurus larval forms of these species. The immediate postacronurus of Figure 1*i* from Wake Island is identified largely because of the prevalence of *A. nigroris* at this island and the apparent absence of *A. nigrofuscus* (as based on collections and observations of W. A. Gosline and the author).

The Phoenix Islands, Swains Island, and Johnston Island are other areas in the Pacific from which *A. nigroris* has been taken and *A. nigrofuscus* is as yet unknown. Forty-seven specimens of *A. nigroris* were collected by L. P. Schultz from the Phoenix Islands and Swains Island. These are not as well differentiated from *A. nigrofuscus* as specimens from other regions such as the Marshall Islands. The caudal fin is slightly more lunate, and the white posterior edge is broader; the black spots at the rear base of the dorsal and anal fins are a little larger. Forty-eight specimens of *A. nigroris* were collected by Gosline, Brock, Yamaguchi, *et al.* from Johnston Island. Also there are several specimens of this species from Johnston in the United States

National Museum and the Bishop Museum. When *A. nigroris* and *A. nigrofuscus* occur together, the latter is usually more prevalent. For example, the 82 specimens of these two species collected by Schultz at Rose Island in the Samoa Islands include only eight *A. nigroris*.

The populations of *A. nigroris* from Johnston Island and the Hawaiian Islands differ significantly from those of other regions of the Pacific in having higher fin ray counts (Table 7), higher gill raker counts (Table 9), and more concave caudal fins. There appear to be slight meristic differences between the species in Johnston Island and the Hawaiian Islands.

The type of *Acanthurus nigroris* Cuvier and Valenciennes is in the Paris Museum. The type locality is Hawaii. According to L. Bertin (personal communication), the specimen is 130 mm. in standard length and has 12 upper and 12 lower teeth (Cuvier and Valenciennes recorded 12 upper and 14 lower teeth). Of the known species of Hawaiian acanthurids, this information alone narrows the possibility to three, *A. nigroris* as here defined, *A. nigrofuscus*, and *A. leucopareius*. Apparently no color markings are now evident on the specimen, but information on the shape of the caudal fin and ends of the dorsal and anal fins clearly eliminates *A. nigrofuscus*. Failure of Cuvier and Valenciennes to mention the vertical white and dark brown bands on the head, so characteristic of *A. leucopareius*, strongly favors the present use of the name *nigroris*.

Jordan and Evermann (1903) were the first to realize that the use of the name *lineolatus* for this species was an error. They proposed the name *atramentatus*. I examined their type of *Teuthis atramentatus* (= *Acanthurus nigroris*) in the United States National Museum.

Through correspondence with A. C. Wheeler of the British Museum, I was able to learn that one of the types of *Acanthurus bipunctatus* Günther is *A. nigroris* and the other is *A. nigrofuscus*. Günther also included specimens



of both of these species as types of *Acanthurus nigros*. For purposes of synonymy I designate as the lectotype of *Acanthurus bipunctatus* Günther the 126 mm. specimen (British Mus. No. 1848.3.13.215) from China. I designate as lectotype of *Acanthurus nigros* Günther the 160 mm. specimen (British Mus. No. 1861.5.31.29) from the New Hebrides. Thus both of these names become synonyms of *Acanthurus nigroris* Cuvier and Valenciennes as the species in here interpreted.

*A. nigroris* appears to range throughout Oceania. The species probably occurs in China, the Philippines, and the East Indies as well. I have seen no specimens from the Indo-Malayan region. Herre's (1927: 422) description of *Acanthurus atramentatus* (Jordan and Evermann) from the Philippines seems to apply to *A. nigroris*; however his figure (pl. 3, fig. 1) is suggestive of *A. nigrofuscus*. Bleeker's (1854a: 101) description of *Acanthurus lineolatus* (not of Cuvier and Valenciennes) from the Banda Islands, East Indies, and that of de Beaufort (1951: 160) check with *A. nigroris*. De Beaufort's reference to a lunate caudal fin and certain variability in color pattern suggests, however, that he also had some specimens of *A. nigrofuscus*.

### *Acanthurus nigrofuscus* (Forskål)

Fig. 2b, Pl. 1

*Chaetodon nigro-fuscus* Forskål (1775: xiii, 64) (Red Sea).

*Chaetodon nigrofuscus* Linnaeus and Gmelin (1788: 1268).

*Acanthurus rubropunctatus* Rüppell (1828: 59, pl. 15, fig. 1) (Red Sea); Günther (1861: 333); Klunzinger (1871: 508) (Red Sea).

*Acanthurus matoides* Cuvier and Valenciennes (1835: 204) (Oualan).

? *Acanthurus lineolatus* Cuvier and Valenciennes (1835: 207) (East Indies).

*Acanthurus nigro-fuscus* Cuvier and Valenciennes (1835: 214) (Réunion and Red Sea).

*Acanthurus rubro-punctatus* Cuvier and Valenciennes (1835: 222).

*Ctenodon rubropunctatus* Swainson (1839: 256).  
*Acanthurus mata*. Day (1876: 205, pl. 48, fig. 1) (seas of India).

*Acanthurus (Rhombotides) nigrofuscus* Klunzinger (1884: 84) (Red Sea).

*Acanthurus gahm*. Day (1888: 789) (*mata* of Day, 1876); Day (1889: 141).

*Acanthurus bipunctatus*. Steindachner (1901: 494) (Honolulu).

*Teuthis bipunctatus*. Jordan and Evermann (1902: 358) (Kotosho Island, Formosa); Jordan and Fowler (1902: 554) (Riu Kiu Islands and Formosa); Jenkins (1903: 479) (Honolulu).

*Hepatus elongatus*. Jordan and Evermann (1905: 389) (Hawaiian Islands); Jordan and Seale (1906: 352) (Samoa); Fowler (in part) (1928: 267) (Oceania); Fowler and Bean (in part) (1929: 213) (Hawaiian Islands); Fowler (1938: 230) (Honolulu); Aoyagi (1943: 208, pl. 6, fig. 18) (Riu Kiu Islands); Kamohara (1954: 52, fig. 13) (Tokara Islands, southern Japan).

*Acanthurus elongatus*. Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1936: 246) (Tuamotu Archipelago and New Hebrides); Schultz (in part) (1943: 165) (Samoa Islands); Schultz and Woods in Schultz *et al.* (1953: 634, pl. 62, fig. D) (Marshall and Mariana Islands); Harry (1953: 148) (Ra-roia, Tuamotu Archipelago).

*Teuthis elongatus*. Barnard (1927: 778) (Natal coast, Africa).

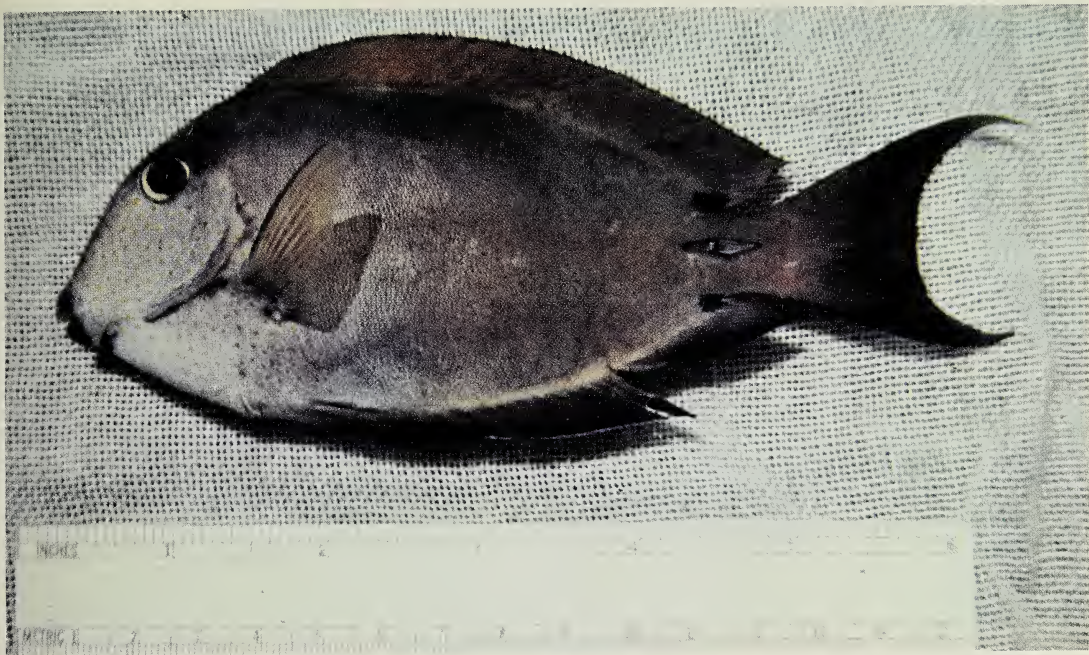
*Acanthurus marginatus*. Herre (1927: 427, pl. 3, fig. 2) (Philippine Islands).

*Acanthurus nigroris*. Herre (1927: 428, pl. 4, fig. 1) (Philippine Islands and Guam); Schmidt (1930b: 103) (Riu Kiu Islands).

*Hepatus fuliginosus*. Fowler (in part) (1928: 266) (Oceania).

*Hepatus lineolatus*. Fowler (in part) (1928: 270) (Oceania); Fowler and Bean (in part) (1929: 228) (Philippine Islands, Mauritius, Samoa, and Hawaiian Islands); Pietschmann (1938: 26, pl. 2, fig. C) (Molokai, Hawaiian Islands).





*Acanthurus nigrofusus*, Hawaiian Islands.



*Acanthurus lineatus*, Gilbert Islands.





*Acanthurus flavoguttatus*. Herre (1936: 245) (New Hebrides).

*Hepatus lucillae* Fowler (1938: 231, fig. 23) (Honolulu).

*Teuthis lucillae* Fowler (1941: 257) (Honolulu); Fowler (1949: 103).

Dorsal rays IX, 24 to 27; anal rays III, 22 to 24; pectoral rays 16 or 17; a 55 mm. specimen has 10 upper and 12 lower teeth; a 79 mm. specimen has 12 upper and 14 lower teeth; a 120 mm. specimen has 12 upper and 14 lower teeth; a 148 mm. specimen has 14 upper and 16 lower teeth. See Table 9 for gill raker counts.

TABLE 8  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus nigrofuscus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS		
	24	25	26	27	22	23	24
Red Sea.....	4				2	2	
Mauritius.....	1	4				2	3
East Indies.....		1	1			1	1
Philippine Islands.....	2	2	1			4	1
Okinawa.....		1				1	
Mariana Islands.....	2	8			1	6	3
Marshall Islands.....	15	24	2		29	12	
Gilbert Islands.....	2		1		1	1	1
Palau Islands.....		2	1			1	2
Samoa Islands.....	14	18	7	1	1	22	17
Hawaiian Islands.....	6	16	4		1	9	16

Caudal fin lunate, caudal concavity 4.5 to 6 in standard length; body depth 2 to 2.3 in standard length; ends of upper teeth tend to be pointed (Fig. 2*b*).

Color (in alcohol) brown, with or without fine bluish gray longitudinal lines on body; a prominent black spot, greater in width than half the diameter of eye, in axil of dorsal fin; a slightly smaller black spot in axil of anal fin; head and chest in life with numerous small bright orange spots which may or may not persist as pale spots in preservative; caudal fin with a distinct dull white posterior bor-

der, about one-half pupil diameter in width at the center and becoming narrow out on lobes (in East Indian and Indian Ocean specimens this border is narrower); an indistinct blackish brown area submarginal to white border of caudal fin; a narrow black margin around socket of caudal spine; lips blackish brown; dorsal and anal fins with faint longitudinal banding in life which is rarely evident on preserved specimens; margin of dorsal and anal fins narrowly dark (blue in life on anal fin); pectoral fin pale with upper edge narrowly black; pelvic fins brown.

*Acanthurus nigrofuscus* appears to reach a larger size in the Hawaiian Islands than in the Marshall, Mariana, and Samoa Islands (island groups from which large collections of this species are available). In Hawaii the species attains a size of at least 152 mm. in standard length. Few specimens from the Marshalls, Marianas, or Samoa exceed 100 mm. in standard length. One 143-millimeter-long specimen was found in a collection from Mauritius.

Although the acronurus is difficult to separate from that of *A. nigroris*, late transforming specimens of *A. nigrofuscus* have been identified from the Hawaiian Islands and the Marshall Islands. The size at transformation in both areas is about 43 mm. A 34 mm. postacronurus from the East Indies is identified as this species.

I know of no type material of *Acanthurus nigrofuscus* (Forskål). The species was described as having a brown-black body and a caudal fin with a whitish posterior edge and lobes which are falcate and half as long as the entire fin. Although the description of *A. nigrofuscus* is brief, it fits the species as here defined better than any other known species of the genus. This is especially true when only the species of *Acanthurus* in the Red Sea and their relative abundance are considered. With the possible exception of *A. sobal* (Forskål) and *A. gabhm* (Forskål), *A. nigrofuscus* appears to be the most common species of the genus in the Red Sea. Although Forskål did not



TABLE 9  
VARIATION IN GILL RAKER COUNTS OF SPECIMENS OF *Acanthurus nigroris* AND *Acanthurus nigrofuscus*  
FROM DIFFERENT LOCALITIES

SPECIES AND LOCALITY	ANTERIOR GILL RAKERS												POSTERIOR GILL RAKERS											
	20	21	22	23	24	25	26	27	28	29	30	31	18	19	20	21	22	23	24	25	26	27		
<i>A. nigroris</i>																								
Marshall Islands.		1	2	2	3	2									3	1	3	2	1					
Phoenix Islands..		1	2	4	3	1									2	3	3	2	1					
Samoa Islands...		1	2	1	3	3								1	2	2	3	2						
Wake Island....			1	3	3										2	1	2	1	1					
Hawaiian Islands.							1	3	3	2	1							1	3	4	2			
Johnston Island..							2	2	3	2		1							2	2	4	2		
<i>A. nigrofuscus</i>																								
Marshall Islands.	2	2	5	1									2	3	3	2								
Samoa Islands...	1	2	5	2	1								1	2	4	3		1						
Hawaiian Islands.		2	3	3	2									3	3	3	1							

state that a black spot was present at the axil of the dorsal and anal fins, these spots could have been overlooked. Specimens of *A. nigrofuscus* in the United States National Museum recently collected from the Red Sea are sufficiently melanistic so that these spots cannot be perceived easily without holding the fish in front of a bright light.

The failure to note these spots by some authors and their observance by others has contributed to the nomenclatorial confusion of this species. More confusing is the evanescent quality of the orange spots on the head. A number of synonyms of *A. nigrofuscus* owe their origin to descriptions from fresh specimens on which the spots are the most conspicuous color feature. Preserved specimens, with these spots faint or absent, have often been listed under different names. Rüppell (1828: 59, pl. 15, fig. 1) described and figured *Acanthurus rubropunctatus* from the Red Sea. He emphasized the small red spots on the head, but did not mention black spots in the axils of the dorsal and anal fins. W. Klausewitz (personal communication) has provided additional information on the types in the Senckenberg Museum at Frankfurt. These have a black spot at the base of the last few dorsal rays and another at the base of the last few anal rays.

I have examined the holotype and paratypes of *Hepatus lucillae* Fowler at the Academy of Natural Sciences of Philadelphia. The specimens are *Acanthurus nigrofuscus*. They were considered distinctive by Fowler largely because of the bright golden spots on the head.

Herre, in his review of Philippine surgeon fishes (1927), listed this species under two names, *Acanthurus marginatus* Cuvier and Valenciennes (with whitish spots on the head) and *Acanthurus nigroris* Cuvier and Valenciennes. The former is a new name for *Acanthurus guttatus* Kittlitz. I was unable to locate Kittlitz' type; it was described as a brown fish with numerous blue spots on the head and body and is either the true *Acanthurus nigroris* or a *Ctenochaetus* (see Randall, in press, a). In 1936 Herre used two different names for *A. nigrofuscus*; these were *Acanthurus flavoguttatus* Kittlitz [probably = *Ctenochaetus striatus* (Quoy and Gaimard)] and *Acanthurus elongatus* (Lacépède).

The name *elongatus* has been applied to the species *Acanthurus nigrofuscus* by other authors as well. Not only is *Chaetodon elongatus* Lacépède a later name than *Chaetodon nigrofuscus* Forskål, but it was used by Lacépède for another species, probably one in the *A. xanthopterus*-*A. mata*-*A. dussumieri* complex.

L. Bertin has supplied me with sufficient

information on the type of *Acanthurus matoides* Cuvier and Valenciennes to enable me to place this name in the synonymy of *Acanthurus nigrofuscus*. The type of *A. matoides* is 120 mm. in standard length, has 12 upper and 12 lower teeth, and a caudal concavity of 23 mm. This name has been most commonly used for the species *Acanthurus xanthopterus* Cuvier and Valenciennes.

Bertin could find no type of *Acanthurus lineolatus* Cuvier and Valenciennes in the Paris Museum. The original description is too brief to permit certain identification. Mention of the shape of the caudal fin and of fine longitudinal blue lines on the body suggests that these authors had specimens of *Acanthurus nigrofuscus*.

**Acanthurus lineatus** (Linnaeus)

Figs. 1e, 2i, Pl. 1

*Chaetodon lineatus* Linnaeus (1758: 274) (Indies).  
*Acanthurus Lineatus* Bloch and Schneider (1801: xxxviii, 214) (East Indies).  
*Acanthurus lineatus* Lacépède (1802: 547, 550); Cuvier and Valenciennes (1835: 223) (East Indies); Bleeker (1853a: 263) (Sumatra); Günther (1861: 333) (East Indies and Philippine Islands); Kner (1865-67: 210) (Tahiti); Günther (1873: 111, pl. 70) (East Indies, Polynesia south of equator, and Indian Ocean); Day (1876: 203) (seas of India); Day (1889: 138); Weber (1913: 317) (East Indies); Herre (1927: 420, pl. 14, fig. 1) (Philippine Islands and Guam); Herre (1936: 242) (Bora Bora and New Hebrides); Schultz (1943: 165) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 33, no. 610) (east coast of Africa south to Delagoa Bay); de Beaufort (1951: 147) (East Indies); Schultz and Woods *in* Schultz *et al.* (1953: 630) (Marshall and Mariana Islands); Harry (1953: 149) (Raroia, Tuamotu Archipelago).  
*Acanthurus vittatus* Bennett, J. W. (1828: pl. 2) (Ceylon).  
*Ctenodon lineatus* Swainson (1839: 256).

*Harpurus lineatus* Forster (1844: 216).  
*Rhombotides lineatus* Bleeker (1863: 235) (Ternate, East Indies).  
*Teuthis lineatus* Seale (1901: 108) (Guam); Schmidt (1930a: 555) (Riu Kiu Islands); Fowler (1946: 198) (Riu Kiu Islands); Fowler (1949: 102) (Jarvis Island and Howland Island).  
*Hepatus lineatus* Jordan and Seale (1906: 351) (Samoa); Evermann and Seale (1923: 78) (Guadalcanal, Solomon Islands); Fowler (1928: 269) (Oceania); Fowler and Bean (1929: 218, fig. 12) (Philippine Islands and East Indies); Fowler (1938: 147, 202) (Tahiti and Christmas Island); Aoyagi (1943: 215, pl. 6, fig. 17) (Riu Kiu Islands).

Dorsal rays IX, 27 to 30; anal rays III, 25 to 28; pectoral rays 16; anterior gill rakers 14 to 16; posterior gill rakers 13 to 15 (raker counts from Samoan specimens); a 107 mm. specimen has 12 upper and 14 lower teeth; a 180 mm. specimen has 14 upper and 15 lower teeth.

TABLE 10  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus lineatus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS			
	27	28	29	30	25	26	27	28
Mauritius.....	1					1		
East Indies.....		1					1	
Palau Islands....	1	4	2				6	1
New Hebrides....	1	1			1	1		
Philippine Islands.	1	1					2	
Mariana Islands...	5	9	3			1	10	6
Marshall Islands..	3	6				3	6	
Gilbert Islands...	5	3				2	4	2
Samoa Islands....	5	2	1			2	5	1
Society Islands...	4	4				3	5	
Marquesas Islands				1				1

Caudal fin strongly lunate, caudal concavity contained 3.3 to 4.5 times in standard length; caudal spine long (its length about



1.9 to 2 in head length), slender, and sharp on both edges; body depth 2.1 to 3 in standard length (in specimens over 100 mm. in standard length).

Color in alcohol: lower one-fourth of body light grayish brown; upper three-fourths with alternate pale yellowish white and broad black near-longitudinal lines, each of the latter bisected with a pale bluish gray line; head with a varying pattern of curved lines similar to those on body (but with black lines narrower); dorsal fin with numerous alternating narrow dark brown and bluish gray lines; anal fin dusky yellow; both dorsal and anal fins with a narrow black margin (extreme edge pale); caudal fin dark brown with vertical dark and light lines at base and a large crescentic area in mid-posterior portion; pectoral fin pale with dusky rays; pelvic fins light yellowish brown, the outer margin black.

Fowler and Bean (1929: fig. 12) demonstrated the variability in color pattern which may be seen in Philippine specimens of this species. The two sides of the same fish may show different patterns of lines.

In addition to the blue, yellow, and black color as seen in adults, four juvenile specimens (37 to 40 mm. in standard length) from the Gilbert Islands displayed bright red color on the dorsal and anal fins (especially posteriorly) and on the caudal fin and pelvic fins.

Four specimens examined from the Marianas, Palaus, and East Indies are in the stage of transformation from the acronurus to the juvenile state at a size of from 27 to 32.5 mm. in standard length.

Museum specimens of transforming *A. nigroris* have been found misidentified as *A. lineatus*. Although both have a linear color pattern in the late acronurus (Fig. 1*e* and *i*), they may be distinguished readily.

*Acanthurus lineatus* is distributed from East Africa to the central Pacific. It appears to be absent from the Red Sea. It is not known from the Hawaiian Islands, Johnston Island, Wake Island, or Marcus Island (Fowler, 1928: 269, was in error in considering *Teuthis striatus*

Bryan and Herre to be *A. lineatus*; the specimens are *A. nigroris*). The extensive collections of fishes from the northern Marshall Islands, which are being reported on by Schultz *et al.* (1953), include only two specimens of this species. In the Gilbert Islands, however, I found *A. lineatus* to be very common, especially in the surge channel habitat. Vernon E. Brock has informed me that the species is common at Palmyra in the Line Islands.

The colorful *A. lineatus* and *A. sobal* are well demarked from other species of *Acanthurus*. They are distinctive in the possession of dark lengthwise bands on the body, strongly lunate caudal fins, and highly developed caudal spines. In addition to being very long and sharp, the spines of these two species are peculiar in being nearly free of sheath.

### *Acanthurus sobal* (Forskål)

Figs. 1*g*, 2*j*, 13

*Chaetodon sobal* Forskål (1775: xiii, 63) (Red Sea).

*Chaetodon Sobar* Linnaeus and Gmelin (1788: 1268) (coasts of Arabia).

*Acanthurus Sobal* Bloch and Schneider (1801: xxxviii, 215) (coasts of Arabia); Cuvier and Valenciennes (1835: 227) (Red Sea).

*Acanthurus carinatus* Bloch and Schneider (1802: 216) (Arabian Sea).

*Aspisurus sobar* Lacépède (1802: 556) (sea of Arabia).

*Choetodon sobab* Cuvier (1817: 331) (after Linnaeus and Gmelin).

*Acanthurus sobal* Rüppell (1828: 56, pl. 16, fig. 1) (Red Sea); Günther (1861: 334) (Red Sea); Klunzinger (1871: 507) (Red Sea).

*Ctenodon Rüppellii* Swainson (1839: 256, fig. 74).

*Acanthurus (Rhombotides) sobal* Klunzinger (1884: 83) (Red Sea).

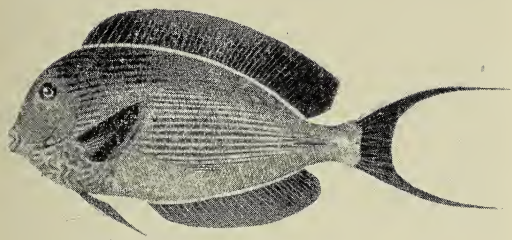


FIG. 13. *Acanthurus sobal* (after Rüppell, 1828).

Dorsal rays VIII, 30 or 31; anal rays III, 28 or 29 (usually 29); pectoral rays 17 (fin ray counts from six specimens from the Red Sea); anterior gill rakers 15 to 17; posterior gill rakers 14 or 15 (raker counts from three Red Sea specimens); an 87 mm. specimen has 12 upper and 14 lower teeth; a 130 mm. specimen has 12 upper and 16 lower teeth; a 206 mm. specimen has 14 upper and 16 lower teeth; a 270 mm. specimen has 16 upper and 18 lower teeth.

Caudal fin strongly lunate, caudal concavity contained about 3 to 4 times in standard length (in specimens over 150 mm. in standard length; an 87 mm. specimen has a caudal concavity which is contained 5 times in its standard length); caudal spine long in adults (1.9 to 2 in head length), slender, very sharp, and without a thick sheath; body depth 2 to 2.2 in standard length; diameter of eye varies from 3 in head length of 87 mm. specimen to 5 in head length of 270 mm. specimen.

Color (in alcohol) light brown with about 15 longitudinal dark brown bands (each about two to three times as broad as intervening light brown bands) on side of body above level of lower part of pectoral fin; on the back a second less conspicuous and more oblique series of bands which become relatively narrower with age; longitudinal dark lines on head dorsal to lower margin of eye; dorsal, anal, and pelvic fins brownish black (smaller

specimens with lengthwise bands in dorsal fin); caudal fin black, shading to dark brown in center, with a narrow pale margin (broader in smaller specimens); pectoral fin dark brown, slightly paler in upper middle portion, with narrow pale posterior margin; caudal spine and margin of socket cream.

Color of a fresh specimen as shown in a photograph (Cousteau, 1952: 461): body below pectoral fin light tan, above with alternating dark brown and pale bluish bands; caudal spine bright orange; dorsal and anal fins black with a narrow blue line at the base which becomes broader posteriorly; anal fin with a narrow blue margin; caudal fin dark brown, shading to black peripherally except narrow margin which is blue; pectoral fin light brown on upper half, dusky blue on lower half, with a black margin all around fin; pelvic fins black with narrow blue margin.

Although this species reaches a large size (at least 270 mm. in standard length), it has a small acronurus. The transforming specimen shown in Figure 1g is 21 mm. in standard length.

*Acanthurus sobal* appears to be confined to the Red Sea.

Al-Hussaini (1947: 40, fig. 10) described the anatomy of the alimentary tract of this species. He stated that it feeds on various kinds of algae, but ingests large amounts of *Sargassum*. I examined the gut content of a 122 mm. specimen; it consisted primarily of fine filamentous green algae.

Fowler and Bean (1929: 216) erroneously applied the name *sobal* to the species *Acanthurus tennentii* Günther.

### *Acanthurus leucocheilus* Herre

Fig. 14

*Acanthurus leucocheilus* Herre (1927: 419, pl. 12, fig. 3) (Philippine Islands); de Beaufort (1951: 140).

The following is based on Herre's description of three specimens, 175 to 200 mm. long, from Bantayan Island, and a 196 mm. spec-



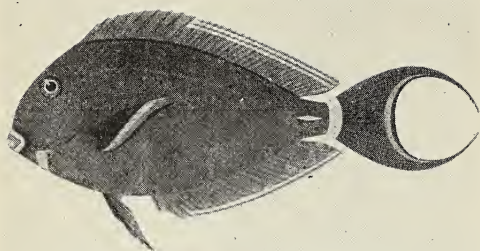


FIG. 14. *Acanthurus leucocheilus* (after Herre, 1927).

imen from Cebu: dorsal rays IX, 24 or 25; anal rays III, 23; 9 or 10 teeth with broad lobate tips on each side of upper jaw and 10 or 11 on each side of lower jaw; depth of body 2 to 2.4 in length; head 3.3 to 3.7 in length; snout 1.3 to 1.44 in head; eye 3.6 to 3.9 in head; eye 1.07 to 1.28 in interorbital; caudal deeply lunate with long pointed tips (caudal concavity in figure about 3.5 in standard length); length of pectoral approximately equal to length of head; first ventral ray elongate, 1.1 to 1.25 in head. Color (in alcohol) blackish brown; snout just above and behind lips black; a bluish white band encircling mouth (though it may be only partially developed on upper lip); a similar but wider white band across chest; a broad bluish white band around base of caudal; pectoral black

with a white bar on posterior third; dorsal, anal, and pelvic fins black or brownish black; caudal fin black, sometimes with a bluish white lunate band near posterior margin; caudal spine white, its groove with a narrow black margin. A fresh specimen, 186 mm. in length, from Agutaya, one of the Cuyo Islands, was blackish brown above, deep brown elsewhere except cheeks and snout which were reddish brown; lips reddish with a bluish band around mouth; the chest band was bluish white; soft dorsal fin with three and anal fin with two dark red lines near margin alternating with bluish; narrow margin of these fins sky blue, posteriorly brick red; caudal fin very dark brown with a wide bluish white band around base and a 'submarginal blue band posteriorly; pectoral blackish brown with a bright yellow bar on posterior third, the margin with rays dusky, membranes clear; pelvics black basally and along outer margin, the rest brick red.

The types of this species were destroyed in Manila during World War II, and to my knowledge, no other specimens are in existence. Herre (1934: 62) recorded the species (as *Acanthurus leucocheilus*) from a specimen (Stanford Mus. No. 26401) from the Philippines. I examined it and found that it is *Acanthurus pyroferus*.

Fowler and Bean (1929: 225) erroneously placed *Acanthurus leucocheilus* Herre in the synonymy of *Hepatus grammoptilus* (Richardson). The specimens which these authors identified as *grammoptilus* are *A. xanthopterus* and *A. dussumieri*. *A. leucocheilus*, as originally described, is probably a valid species.

### *Acanthurus pyroferus* Kittlitz

Figs. 2*k*, 15

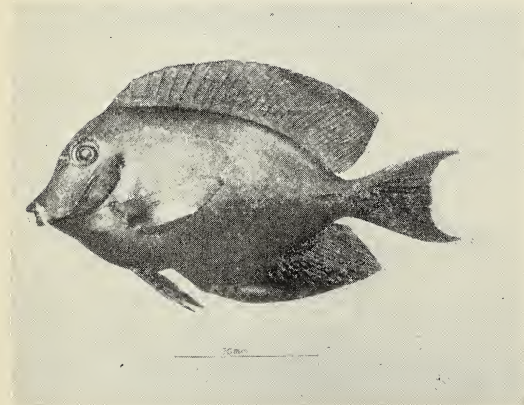


FIG. 15. *Acanthurus pyroferus*. 113 mm. specimen, Marshall Islands (after Schultz and Woods, 1953, retouched).

*Acanthurus pyroferus* Kittlitz (1834: 191, pl. 12, fig. 2) (Ulea Island = Woleai Atoll, Caroline Islands); Günther (1861: 337); Günther (1873: 113).

*Acanthurus armiger* Cuvier and Valenciennes (1834: 234).

*Acanthurus celebicus* Bleeker (1852: 761) (Macassar, Celebes); Kner (1865–67: 211) (Madras); Günther (1861: 339); Günther (1873: 115, pl. 73, fig. B) (Solomon Islands and Tahiti); Day (1889: 142) (Malay Archipelago); Herre (1927: 417, pl. 13, fig. 1) (Mindoro, Philippine Islands); de Beaufort (1951: 141) (Java and Adonare).

*Acanthurus fuscus* Steindachner (1861: 176, pl. 5) (Ambon, East Indies); Günther (1861: 339); de Beaufort (1851: 137).

*Rhombotides celebicus* Bleeker (1863b: 235) (Ternate, East Indies).

*Acanthurus Celebicus* Day (1876: 206) (Malay Archipelago).

*Acanthurus tristis* Tickell in Day (1888: 788) (Arraken, Burma); Myers (1951: 26).

*Hepatus pyroferus* Jordan and Seale (1906: 350) (error for *pyroferus*).

*Hepatus celebicus* Jordan and Seale (1906: 352); Jordan and Seale (1907: 34) (Philippine Islands).

*Hepatus pyroferus* Fowler (1928: 272).

*Hepatus leucosternon*. Fowler (1928: 272); Fowler and Bean (in part) (1929: 243, fig. 14) (Riu Kiu Islands, Philippine Islands, and East Indies); Aoyagi (1943: 207, text fig. 52, pl. 5, fig. 13) (Riu Kiu Islands).

*Acanthurus leucocheilos*. Herre (1934: 62) (Linapacan, Philippine Islands).

*Acanthurus leucosternon*. Schultz and Woods in Schultz *et al.* (1953: 626, pl. 61, fig. B) (Bikini Atoll, Marshall Islands).

Dorsal rays VIII, 27 or 28; anal rays III, 24 to 26; pectoral rays 16; anterior gill rakers 23 to 26; posterior gill rakers 25 to 27 (raker counts from four specimens from the Marshall Islands); a 109 mm. specimen has 14 upper and 16 lower teeth; a 145 mm. specimen has 16 upper and 18 lower teeth; a 159 mm. specimen has 16 upper and 21 lower teeth.

Snout somewhat produced; snout length 4.6 to 4.7 in standard length; caudal fin lunate, caudal concavity 4 to 5 in standard length; longest dorsal ray about 4.5 in standard length.

TABLE 11  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus pyroferus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS		ANAL SOFT RAYS		
	27	28	24	25	26
Philippine Islands . . . .	5		1	4	
Marshall Islands . . . . .	2	2		2	2

Color from a 35 mm. Kodachrome transparency (given to me by Leonard P. Schultz) of a Marshall Islands specimen (reproduced in black and white herein as Figure 15): purplish black with an orange area, higher than wide, at edge of gill opening just above base of pectoral fin; a diffuse patch of orange anterior to base of pectoral and a trace of orange just behind eye; a broad black band beginning at upper end of gill opening and extending on to margin of gill cover down to isthmus (this band is more apparent in preserved specimens, as is a black band at the base of the dorsal fin, one at the base of the anal fin, blackish lips, and a narrow black margin around caudal spine socket); a white line under chin extending slightly above rictus; median fins black except for a broad posterior band on back edge of caudal fin which is pale yellow; pectoral fin blackish, especially basally on rays, with a large pale yellow spot in lower central part of fin.

Kittlitz (1834) stated that the species is common at Ulea (Caroline Islands), and the young are dirty yellow in color. I have seen no juvenile specimens of this species. It is possible that Kittlitz might have confused the young of *Acanthurus olivaceus*, which are yellow, with *Acanthurus pyroferus*.

*Acanthurus pyroferus* occurs in the East Indies and Philippines and into the Indian Ocean at least as far as India. It ranges out into the tropical central Pacific; however it is recorded from only a few of the major island groups. De Beaufort (1951: 142) lists the species (as *A. celebicus*) from Hawaii. In this I believe he is in error.



I know of no type specimen of *Acanthurus pyroferus* Kittlitz. Although no one has identified a specimen of *Acanthurus* as *pyroferus* since Kittlitz (1834), and de Beaufort (1951: 138) regarded it as a problematic species, there is little doubt that it is the same as *Acanthurus celebicus* Bleeker. Kittlitz' figure shows the vertically aligned orange area, which is edged in black, just above the pectoral fin and the prominent, uniformly broad, yellow, posterior margin on the caudal fin. The dorsal and anal fins are relatively elevated, and the snout is produced (although this feature seems to be exaggerated). The dorsal and anal fin ray counts (D VII, 29; A III, 25) check closely (as in most species of *Acanthurus*, the first dorsal spine is very short and covered with skin; it could have been overlooked by Kittlitz, or he may have counted the eighth spine as a soft ray). The narrow ring of white under the chin is not present on the figure, nor is it mentioned in the description. Probably it was missed. There are greater omissions than this from some of the figures and descriptions of better known species of acanthurids from the same paper.

Herre (1927: 418) observed two living specimens from the Philippines and reported that the amount and intensity of red color behind the head and about the pectoral base vary considerably according to light conditions and the state of excitement of the fish.

*Acanthurus tristis* Tickell (Day) was described as having a caudal fin "nearly white externally" and an irregular black band from the upper edge of the orbit across the top of the opercle to the base of the pectoral fin. Although I have not seen a specimen of *Acanthurus pyroferus* with the black band extending to the eye, Herre's plate (1927: pl. 13, fig. 1) shows this pattern, and I consider it as probably within the range of variability of the species.

*Acanthurus pyroferus* appears to link the group of three species, *Acanthurus leucosternon*, *Acanthurus glaucopareius*, and *Acanthurus achilles* with the last 11 Indo-West-Pacific species

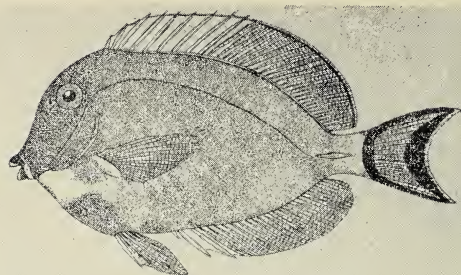


FIG. 16. *Acanthurus leucosternon* (after de Beaufort, 1951).

as discussed in this paper (species such as *A. olivaceus*, which have a distinctive color mark on the shoulder region, and large species such as *A. xanthopterus*) and the Atlantic species except *A. coeruleus*. *A. pyroferus* is intermediate in dorsal and anal fin ray counts, tooth structure, and tooth counts. It has a produced snout and white line on the chin in common with the former group and the large, round, gizzard-like stomach of the latter.

### *Acanthurus leucosternon* Bennett

Figs. 21, 16

*Acanthurus leucosternon* Bennett, E. T. (1832: 183) (Ceylon); Bleeker (1853b: 48); Bleeker (1856-57: 237) (Batoe Islands, Sumatra); Günther (1861: 340) (Ceylon); Playfair in Playfair and Günther (1866: 56) (Zanzibar); Day (1876: 203); de Beaufort (1951: 139, fig. 26) (Pulu Weh and coast of Deli, Sumatra).

*Acanthurus Delisiani* Cuvier and Valenciennes (1835: 193) (Mauritius).

*Acanthurus Delisianus* Valenciennes in Cuvier (1837: pl. 45); Guérin (1844: pl. 35, fig. 2).

*Rhombotides leucosternon* Bleeker in Bleeker and Pollen (1874: 97).

*Acanthurus leucosternum* Day (1889: 138).

Dorsal rays IX, 30; anal rays III, 27; pectoral rays 16; 11 upper teeth and 12 lower teeth. All counts based on one 173 mm.

specimen from Mauritius in the Museum of Comparative Zoology at Harvard College. This specimen, the only one which I have examined, was used for the proportional measurements and color description below.

Body depth 1.7 in standard length; caudal concavity 13 in standard length; longest dorsal ray 5.4 in standard length; caudal spine 3 in head length.

Color in alcohol: body bluish gray; head dark brown; chin with a chalky white line at edge of lip which extends a distance equivalent to half the diameter of an eye above the rictus and narrows to a point apically; a broad chalky white band on chest, as wide as depth of caudal peduncle, extending to base of pectoral fin; caudal fin with a white posterior marginal band (equal in width to one-third the diameter of the pupil of the eye), a brownish black submarginal band (an eye diameter in width centrally, but narrowing toward lobes where it meets brownish black upper and lower edges of caudal fin), and a narrow brownish black band across base which connects the dark upper and lower margins of caudal lobes; dorsal fin pale yellow with a narrow white marginal line on upper edge and a black submarginal line; anal fin pale yellow with narrow white outer margin and white line at base; pectoral fin pale yellow; pelvic fins purplish gray with a white margin; region around caudal spine slightly paler than body.

*Acanthurus leucosternon* resembles *Acanthurus achilles* and *Acanthurus glaucopareius* in morphology and color. It ranges from East Africa to the East Indies, and does not appear to be a common species.

Fowler (1928), Fowler and Bean (1929), Aoyagi (1943), and Schultz and Woods (1953) were all in error in their use of the name *leucosternon* for the species *Acanthurus pyroferus*.

***Acanthurus glaucopareius* Cuvier**

Figs. 1*l*, 2*m*, Pl. 2

*Acanthurus glauco-pareius* Cuvier (1829: 224)

(after Seba) (Günther, 1861, gives the type locality as Tahiti).

*Acanthurus ali-ala* Lesson (1830: 150) (Oualan).

*Acanthurus glaucopareius* Kittlitz (1834: 192, pl. 13, fig. 3) (Ulea Island = Woleai Atoll, Caroline Islands); Cuvier and Valenciennes (1835: 190) (Tahiti); Bleeker (1856: 47) (Ambon, East Indies); Günther (1861: 339) (Ambon, East Indies and Tahiti); Günther (1873: 114, pl. 71, fig. A) (Polynesia and East Indies); Schultz (1943: 161) (Phoenix and Samoa Islands); Marshall, N. B. (1950: 194) (Cocos-Keeling Islands); Palmer (1950: 202) (Christmas Island, Indian Ocean); de Beaufort (1951: 138) (Ambon, Misol, and New Guinea).

*Rhombotides glaucopareius* Bleeker (1865: 288) (Ambon, East Indies).

*Teuthis aliala* Jordan and Evermann (1898: 1693) (Clarion and Socorro Islands, western Mexico); Jordan and McGregor (1899: 280) (Clarion and Socorro Islands); Seale (1901: 109) (Guam).

*Hepatus aliala* Snodgrass and Heller (1905: 403) (Cocos Island and Clipperton Island); Jordan and Seale (1906: 350) (Samoa); Aoyagi (1943: 209, pl. 8, fig. 2, pl. 6, fig. 19) (Okinawa).

*Acanthurus aliala* Herre (1927: 416, pl. 2, fig. 2) (Philippine Islands); Herre (1936: 241) (Cocos Island off Costa Rica, Marquesas Islands, Tuamotu Archipelago, and Society Islands); Schultz and Woods in Schultz *et al.* (1953: 627, pl. 65, fig. A) (Marshall Islands).

*Hepatus glaucopareius* Fowler (1928: 272) (Oceania); Fowler and Bean (1929: 246) (Philippine Islands, Guam, Samoa, and Honolulu).

*Hepatus aliala japonicus* Schmidt (1930*b*: 102, pl. 6, fig. 3) (Riu Kiu Islands).

*Teuthis glaucopareius* Whitley and Colefax (1938: 297) (Nauru Island).

*Hepatus glauco-pareius* Fowler (1938: 103) (Takaroa, Tuamotu Archipelago).

*Teuthis japonicus* Fowler (1946: 197).



*Teuthis glauco-pareius* Fowler (1949: 103) (Jarvis Island).

*Acanthurus* sp. one Harry (1953: 149) (Raroia, Tuamotu Archipelago).

Dorsal rays IX, 28 to 31; anal rays III, 26 to 28; pectoral rays 16; anterior gill rakers 17 to 19; posterior gill rakers 18 to 20 (raker counts from specimens from the Phoenix Islands); 80 mm., 108 mm., and 133 mm. specimens have 10 upper and 10 lower teeth; 153 mm. and 171 mm. specimens have 10 upper and 12 lower teeth.

TABLE 12  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus glaucopareius* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS		
	28	29	30	31	26	27	28
East Indies.....			1			1	
Philippine Islands.....	1				1		
Mariana Islands.....		1	1		1	1	
Marshall Islands.....	2	6	6	1	2	12	1
Gilbert Islands.....	1	7	3	1	5	6	1
Samoa Islands.....		3	4	1	2	5	1
Phoenix Islands.....	1	3	6	2	3	9	
Tuamotu Archipelago.	2	3	4		2	5	2
Marquesas Islands....		1			1		
Line Islands.....		1				1	
Galapagos Islands....		1	1	1		2	1
Cocos Island,							
Costa Rica.....	1	3	4		2	4	2
Hawaiian Islands.....		1	1			2	

Depth of body 1.7 to 1.85 in standard length; caudal concavity 10 to 14.5 in standard length; width of mouth from rictus to rictus 4.5 to 5.3 in head length; length of snout 4 to 4.3 in standard length.

Color (in alcohol) dark purplish brown; a whitish elliptical area below and adjacent to eye; a pale line under chin extending and narrowing about one-half eye diameter in distance above rictus; no pale area around caudal spine and no white mark on opercle; caudal fin abruptly yellowish white with a pale yellow band (the posterior edge of which

is bordered with a narrow dark line), about one-fourth to one-third the diameter of the eye in width, in outer part of fin paralleling posterior margin; dorsal and anal fins colored like body except basally where there is a prominent pale yellowish white (yellow in life) band which broadens posteriorly in fin to about three-fourths the length of the last few rays; dorsal and anal fins with a narrow white margin and a black submarginal line; rays of pectoral fin dusky, membranes clear; pelvic fins dark with narrow pale outer margin.

Marshall (1950: 194) and Palmer (1950: 202) recorded a color form of this species which co-exists with the normal one at Cocos-Keeling Islands and Christmas Island, respectively, in the Indian Ocean. The salient feature of this form is the lack of the usual sharp dividing line in color at the caudal flexure. There is a gradual blending of dark body color and pale caudal color over the proximal one-third of the fin. Also the dorsal and anal fins are paler.

Schmidt (1930b: 102, pl. 6, fig. 3) described a subspecies, *Acanthurus glaucopareius japonicus*, from the Riu Kiu Islands which Fowler (1946: 197) elevated to species rank. Aoyagi (1943: 210), however, observed this form occurring with the typical *Acanthurus glaucopareius* in the Riu Kius and found intermediates between the two. I examined a 90 mm. specimen of the *japonicus* form at the Academy of Natural Sciences of Philadelphia. It differs from the normal *glaucopareius* chiefly in the presence of a broad pale band running from the eye to the posterior half of the upper lip and a large pale spot at the base of the pectoral fin. There are no obvious meristic differences; the counts of this specimen are: D IX, 28; A III, 26; P 16; 10 upper teeth; 10 lower teeth.

Schultz (1943: 157, 163, fig. 13) described *Acanthurus rackliffei* from the Phoenix Islands. He noted the similarity to *Acanthurus glaucopareius* and *Acanthurus achilles*. In my opinion *A. rackliffei* is a hybrid between these two species (Randall, in press, d).

*Acanthurus glaucopareius*, *Acanthurus achilles*, and *Acanthurus leucosternon* stand apart from other species of the genus principally in having a produced snout, a small mouth with few, relatively large teeth of distinctive structure, a high body, dark purplish color, and a white line on the chin. Also, at least in *A. achilles* and *A. glaucopareius*, the size at transformation from the acronurus to the juvenile stage is very large, about 55 to 60 mm. in standard length. These differences would probably warrant recognition of this group as a subgenus were it not for *Acanthurus pyroferus* which links these three to other species of *Acanthurus*.

The largest specimen of *A. glaucopareius* examined by me measures 171 mm. in standard length. It was collected from Enderbury Atoll in the Phoenix Islands.

*Acanthurus glaucopareius* appears to be absent from the Indian Ocean except for Christmas and Cocos-Keeling Islands. It occurs in the East Indies and Philippine Islands and is recorded from most of the island groups of the tropical Pacific. It is one of the three species of *Acanthurus* to have crossed the eastern Pacific barrier; it seems to be common in the waters of the Galapagos Islands, Cocos Island, and the Revillagigedo Islands (Mexico). It is usually abundant where it is found; however it is probably the rarest of the species of surgeon fishes in the Hawaiian Islands.

In atolls of the Gilbert Islands, *A. glaucopareius* was most commonly seen on the coral-liferous terrace of the outer reef, especially near the entrances to surge channels; however, it was often observed in coral-rich areas of more sheltered waters.

Many authors have used the name *Acanthurus aliala* Lesson (1830) for this species. It is true that the name *glaucopareius* does not appear on page 212 of Bloch and Schneider (1801) even though a description which fits this species can be found on this page in a separate section under the heading *Acanthurus nigricans*. Cuvier's listing (1829: 224) of *Acanthurus glaucopareius* and reference to

the work of the prelinnaean author Seba (1758) who figured the species, however, clearly predates Lesson.

### *Acanthurus achilles* Shaw

Figs. 1*k*, 2*n*, Pl. 2

*Acanthurus Achilles* Shaw (1803: 383) (no locality); Cuvier and Valenciennes (1835: 218).

*Acanthurus achilles* Günther (1861: 340) (China); Günther (1873: 115, pl. 71, fig. B) (Polynesia); Waite (1897: 188) (Funafuti, Ellice Islands); Steindachner (1901: 493) (Honolulu); Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1927: 414, pl. 2, fig. 1) (Guam); Schultz (1943: 162) (Phoenix and Samoa Islands); Schultz and Woods in Schultz *et al.* (1953: 629, pl. 65, fig. B) (Marshall Islands); Harry (1953: 147) (Raroia, Tuamotu Archipelago).

*Acanthurus aterrimus* Günther (1873: 114, pl. 77, fig. B) (Samoa).

? *Acronurus formosus* Castelnau (1873: 104) (Torres Strait); Macleay (1881: 528).

*Tenthis achilles* Fowler (1899: 494) (Caroline Islands); Jenkins (1903: 475) (Hawaiian Islands).

*Hepatus achilles* Jordan and Evermann (1905: 384, pl. 58) (Honolulu); Jordan and Seale (1906: 350) (Samoa); Fowler (1928: 273) (Oceania); Fowler and Bean (1929: 247) (Fanning Island, Samoa, and Hawaiian Islands); Fowler (1938: 104, 184) (Takaroa, Tuamotu Archipelago and Tongareva).

*Hepatus aterrimus* Jordan and Seale (1906: 351); Fowler (1928: 268) (Society Islands); Fowler and Bean (1929: 243).

*Tenthis aterrimus* Fowler (1949: 103).

Dorsal rays IX, 29 to 33; anal rays III, 26 to 29; pectoral rays 16; anterior gill rakers 16 to 20; posterior gill rakers 18 to 20 (raker counts from specimens from the Phoenix Islands); 84 mm., 140 mm., and 155 mm. specimens have 8 upper and 10 lower teeth; a 185 mm. specimen has 10 upper and 12 lower teeth.



TABLE 13  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus achilles* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS					ANAL SOFT RAYS				
	29	30	31	32	33	26	27	28	29	
Marshall Islands.....	2	10	12	7		1	7	14	9	
Gilbert Islands.....			4				1	3		
Samoa Islands.....			6	10	16		4	13	15	
Phoenix Islands.....	1	3	5	2			3	6	2	
Line Islands.....	2	1	2			1	1	2	1	
Malden Island.....	1	1	1				3			
Wake Island.....		3	3	1			2	4	1	
Hawaiian Islands.....	1	4	8	4	2	1	4	8	6	
Johnston Island.....			8	2				6	4	

Depth of body 1.75 to 1.9 in standard length; caudal concavity 5.5 to 8 in standard length; width of mouth from rictus to rictus 4.5 to 6 in head length; length of snout 3.9 to 4 in standard length.

Color (in alcohol) blackish brown with a large oval pale yellow (orange in life) area extending forward from rear of caudal spine; broad median portion of opercular membrane snow white; pale line on chin ending at rictus; basal one-third of caudal fin dark like body; next one-third of fin light orangish brown, bordered posteriorly with a prominent black band which follows the contour of the hind edge of the fin; outer one-fourth to one-third of caudal fin white; dorsal and anal fins colored like body except for a pale line at the base which is only slightly broader posteriorly than anteriorly and a narrow white margin; pectoral rays black, membranes pale; pelvics dark brown with outer margins white.

The large elliptical orange spot on the posterior part of the body of *A. achilles* does not appear until a standard length of about 65 to 70 mm. is attained. Günther (1873) described a juvenile *A. achilles* which had not yet developed its orange spot as a new species, *A. aterrimus*. Schultz (1943: 162) corrected this error.

The acronurus of *A. achilles* (Fig. 1*k*) reaches a large size, about 60 mm. in standard length.

It is spotted with black, a characteristic which one usually associates with the acronuri of *Naso*.

*Acronurus formosus* Castelnau may be the acronurus of *A. achilles*. It was described as having four rows of black spots and the dorsal and anal fin ray counts were high as in *achilles*. Whitley (1940: 425) selected the largest of Castelnau's specimens (62 mm. in standard length) as lectotype and figured it (fig. 42), but did not show any spots. Whitley's counts are also high (D VIII, 31?; A III, 32?). The specimen was collected from the Torres Strait which separates New Guinea from Australia. *Acanthurus achilles* is not recorded from the East Indies, which suggests that the specimen may be the acronurus of *A. leucosternon* which I have not seen.

*Acanthurus achilles* is common throughout Oceania. It is not known from the Indian Ocean. With the possible exception of the specimen of *Acronurus formosus*, it appears to be absent from the East Indies. The only record of *A. achilles* from the Philippine Islands is the listing of the name with a question mark by Elera (1895: 532). As he did not include *A. glaucopareius* among the surgeon fishes in his catalog, it seems possible that he might have confused these two species. Herre (1927) included *A. achilles* in his work on Philippine surgeon fishes only because he believed the species should occur there. Fowler and Bean (1929) did not find any specimens among the extensive "Albatross" collections of fishes from the Philippines and East Indies; these authors recorded the species from the Philippines on the strength of Elera's dubious record. Herre (1953: 532) erred in listing *achilles* in his checklist of fishes of the Philippines on the basis of his 1927 work. *A. achilles* is not known from the Riu Kiu Islands or Japan. Günther (1861: 340), however, listed it from China; this record is inconsistent with the known distribution and should be checked.

*Acanthurus achilles* is most often found in inshore regions of moderately rough water.

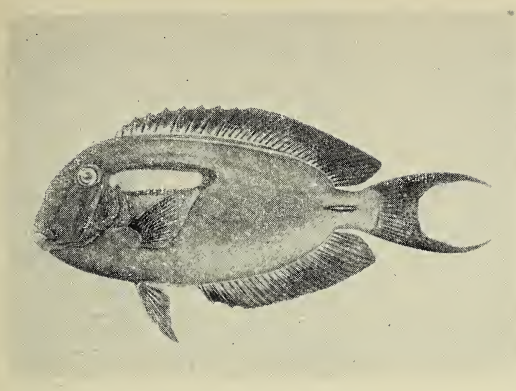


FIG. 17. *Acanthurus olivaceus* (after Schultz and Woods, 1953, retouched).

At atolls in the Gilbert Islands the species was frequently observed in surge channels of the windward reef.

The largest specimen seen by me is 195 mm. in standard length; it was collected at Malden Island.

For further remarks on *A. achilles* see discussion under *A. glaucopareius*.

***Acanthurus olivaceus* Bloch and Schneider**  
Figs. 1f, 2o, 17

*Acanthurus Nigricans* var. *Olivaceus* Bloch and Schneider (1801: xxxviii, 213–214) (Tahiti).

*Acanthurus eparei* Lesson (1830: 147, pl. 27, fig. 1) (Tahiti).

*Acanthurus olivaceus* Kittlitz (1834: 189, pl. 12, fig. 1) (Caroline Islands); Günther (1861: 336) (Tahiti and Fiji Islands); Günther (1873: 113) (East Indies and South Seas); Steindachner (1901: 493) (Honolulu); Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1927: 413, pl. 12, fig. 1) (Philippine Islands); Schultz (1943: 166) (Samoa Islands); de Beaufort (1951: 154) (East Indies); Schultz and Woods in Schultz *et al.* (1953: 632, pl. 67) (Marshall Islands).

*Acanthurus humeralis* Cuvier and Valenciennes (1835: 231) (Caroline Islands and Tahiti); Eydoux and Souleyet (1841: 169, pl. 2, fig. 3) (Hawaiian Islands); Bleeker (1852: 762) (Macassar, Celebes).

*Ctenodon erythromelas* Swainson (1839: 256) (error or emendation for *Acanthurus eparei* Lesson).

*Harpurus paroticus* Forster (1844: 183).

*Acanthurus chrysosoma* Bleeker (1857: 67) (Kajeli); Günther (1861: 332); de Beaufort (1951: 165) (East Indies).

? *Rhombotides xanthosoma* Bleeker (1865: 288) (error for *chrysosoma*?).

*Rhombotides olivaceus* Bleeker (1865: 288) (Ambon, East Indies).

*Teuthis olivaceus* Seale (1901: 107) (Guam); Jordan and Evermann (1902: 358, fig. 23) (Formosa); Jenkins (1903: 476) (Hawaiian Islands).

*Hepatus olivaceus* Jordan and Evermann (1905: 385, fig. 166); Jordan and Seale (1906: 350) (Samoa); Jordan and Richardson (1908: 270) (Cagayancillo, Philippine Islands); McCulloch (1922: 243) (Capricorn Islands, Queensland); Fowler (1928: 271) (Oceania); Fowler and Bean (1929: 231) (Philippine Islands, Okinawa, Samoa, and Hawaiian Islands); Schmidt (1930a: 556) (Riu Kiu Islands); Fowler (1931: 345) (Honolulu); Fowler (1938: 232) (Honolulu); Aoyagi (1943: 211, pl. 5, fig. 15, teeth only) (Riu Kiu Islands); Hiyama (1943: 94, pl. 20, fig. 55).

*Hepatus chrysosoma* Fowler (1928: 269); Fowler and Bean (1929: 214).

Dorsal rays IX, 23 to 25; anal rays III, 22 to 24; pectoral rays 16 or 17 (usually 17); anterior gill rakers 24 to 28; posterior gill rakers 23 to 27 (raker counts from Hawaiian specimens); a 44 mm. specimen has 14 upper and 14 lower teeth; a 123 mm. specimen has 14 upper and 16 lower teeth; a 138 mm. specimen has 16 upper and 18 lower teeth; a 208 mm. specimen has 18 upper and 20 lower teeth; a 225 mm. specimen has 20 upper and 21 lower teeth.

Caudal fin of adults strongly lunate, caudal concavity (in specimens greater than 180 mm. in standard length) contained 4 to 5 times in standard length; in specimens about 100 mm.



TABLE 14  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus olivaceus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	23	24	25	22	23	24
Philippine Islands . . . .		3		1	2	
Okinawa . . . . .	1	2		1	2	
Mariana Islands . . . . .		2		1		1
Caroline Islands . . . . .	1			1		
Marshall Islands . . . . .	2	12	4	3	9	6
Gilbert Islands . . . . .		1	1	1		1
Samoa Islands . . . . .	2	3		2	3	
Society Islands . . . . .	1	1			2	
Hawaiian Islands . . . . .	2	13	3	5	10	3
Johnston Island . . . . .			1		1	

in standard length, the caudal concavity is contained about 9 times in the standard length; snout length 4.5 to 4.9 in standard length; longest soft dorsal ray 5.5 to 6 in standard length; eye of 104 mm. specimen 3.3 in head length; eye of 208 mm. specimen 4.5 in head length; caudal spine of 104 mm. specimen 3.5 in head length; caudal spine of 208 mm. specimen 2.5 in head length.

Large adult males (about 170 mm. or greater in standard length) develop a definite convexity in the profile of the snout which may permit determination of the sex of specimens without resorting to examination of the gonads. This sexual dimorphism of large adults is evident to a greater or less degree in the remaining Indo-West-Pacific species considered in this work and possibly also the Atlantic species except *A. coerulens*. In most of the species the profile of the head of the female also becomes more convex with age. Males the same size, however, show distinctly greater convexity than females. All of these species have a large, round, very thick-walled stomach.

Color in life from a 35 mm. Kodachrome transparency taken by the author of a 132 mm. specimen speared at Arno Atoll, Marshall Islands: dark grayish brown with a bright orange horizontal band, broadly bor-

dered with purplish black, extending posteriorly from upper end of gill opening a distance greater than the length of the head; a dull orange line at base of dorsal fin; a similar, but fainter, line at base of anal fin; a large crescentic white area in centro-posterior part of caudal fin; rest of caudal fin, especially the lobes, spotted with dark brown; other fins colored like body except outer portion of pectoral which is pale; a faint longitudinal banding may be seen in soft portion of dorsal fin. Many adult specimens have been observed on which the color of the body posterior to a vertical at about the level of the fifth dorsal soft ray is much darker than that in front of this demarcation.

D. W. Strasburg (MS) has pointed out that the young of *Acanthurus olivaceus* are yellow. From a transformation size of about 29 mm. in standard length to a length of about 55 mm. the body color is bright yellow. The margins (except posterior) of the median fins and lateral outer edge of the pelvic fins are narrowly black. At a size of about 45 mm. in standard length the mark on the shoulder region first makes its appearance as a small dusky area. Specimens larger than about 55 mm. in standard length show a progressive accumulation of brown pigment until, at a standard length of about 85 mm., the brown color predominates. The shoulder bar first acquires a pale orange center at a standard length of about 55 mm.

*Acanthurus chrysosoma* Bleeker is probably the young of *Acanthurus olivaceus*. Bleeker's type specimens were 43 to 51 mm. in length. The color when fresh was orange-yellow with brownish edges on the dorsal, anal, and caudal fins.

*A. olivaceus* occurs from the East Indies to Oceania. Records from the Indian Ocean, such as from Mauritius, all appear to be the closely related *A. tennentii*.

*A. olivaceus* is usually found in fairly deep water, about 30 feet or more in depth. It is most commonly seen where much of the bottom is sandy.

**Acanthurus tennenti** GüntherFigs. 2*p*, 18*Acanthurus tennenti* Günther (1861: 337) (Ceylon); Day (1889: 140).*Acanthurus Tennentii* Day (1876: 204).*Acanthurus plagiatus* Peters (1876: 439) (Mauritius).*Acanthurus olivaceus*. Sauvage (1891: 343) (Mauritius).*Hepatus sobal*. Fowler and Bean (1929: 216) (locality unknown).

Dorsal rays IX, 23 or 24; anal rays III, 22 or 23; pectoral rays 16 (fin ray counts from 7 specimens from Mauritius and Ceylon); anterior gill rakers 25, posterior gill rakers 25 (based on one specimen); a 105 mm. specimen has 15 upper and 16 lower teeth; a 214 mm. specimen has 20 upper and 22 lower teeth.

Caudal fin lunate, caudal concavity varying from 10 in standard length of a 105 mm. specimen to 5 in standard length of a 214 mm. specimen.

Color (in alcohol) brown with a horseshoe-shaped black mark (open end pointing anteriorly) just behind upper edge of gill opening, at level of eye (in specimens of about 120 mm. or more in standard length this mark is broken posteriorly, forming two longitudinal curved bands; in very large specimens these bands are straighter, more elongate, and attenuate posteriorly); caudal spine enclosed in a prominent black area which, in turn, is surrounded by a bluish white region. This dark area becomes progressively larger with age and its bluish white margin relatively narrower (in a 214 mm. specimen the black area was oval in shape, slightly more pointed anteriorly, 37 mm. in length and 16 mm. high; the bluish white margin was a little greater than 1 mm. in width); caudal fin with a broad crescentic white area posteriorly; large specimens with pale margins on the very elongate upper and lower caudal lobes; dorsal and anal fins brown with no trace of banding; pectoral fin brown with a broad pale posterior

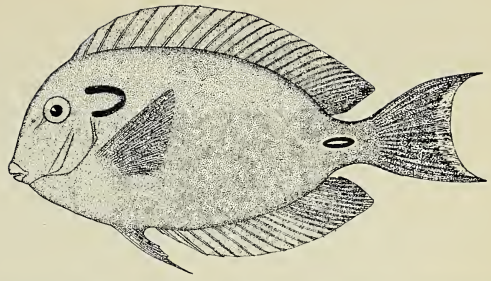


FIG. 18. *Acanthurus tennenti*. 116 mm. specimen, locality unknown. Drawing by author.

margin (more distinct in large specimens); pelvic fins brown.

Fowler and Bean (1929: 216) misidentified a 116 mm. specimen of this species (U.S.N.M. No. 21294) as *Hepatus sobal*. It is this specimen which I have drawn as Figure 18. No field data or locality are available.

A. C. Wheeler kindly sent an X-ray, a drawing, and other data on the type specimen in the British Museum. The specimen is 103 mm. in standard length and is conspecific with the Fowler and Bean specimen.

Peters (1876: 439) described *Acanthurus plagiatus* as having two elongate triangular black marks on the shoulder, a black area with blue margin around the caudal spine, and a lunate caudal fin with a broad yellow posterior margin and a narrow yellow edge on the upper and lower caudal lobes. Had I not seen the five specimens in the Museum of Comparative Zoology at Harvard College which connect the large *plagiatus* form to *A. tennenti* of a little over 100 mm. in standard length, I would have probably considered Peters' species as valid.

*Acanthurus tennenti* is very closely related to *Acanthurus olivaceus*, and, with the possible exception of pectoral fin ray counts (more specimens needed), I can separate the two only by color. To my knowledge they are not known from the same area, *A. tennenti* occurring in the Indian Ocean and *A. olivaceus* in the East Indies and Oceania. Sauvage (1891: 343) (after Liénard) recorded *A. olivaceus* from Mauritius; however, he described it as having



two oblong black marks on the suprascapular region, thus indicating that he had a large specimen of *A. tennenti*. It is possible that the distinction between *A. olivaceus* and *A. tennenti* is subspecific; however, the color differences as noted in the key are greater than those seen on other similar pairs of acanthurids (such as *Acanthurus xanthopterus* and *Acanthurus mata*) which may be observed together.

***Acanthurus fowleri* de Beaufort**

Fig. 2q, Pl. 3

*Acanthurus bariene*. Herre (in part) (*non* Lesson) (1927: 409) (Bantayan Island, Philippine Islands).

*Hepatus pyroferus*. Fowler and Bean (*non* Kittlitz) (1929: 232) (Philippine Islands and East Indies).

*Acanthurus fowleri* de Beaufort (1951: 149) (after Fowler and Bean).

Dorsal rays IX, 27; anal rays III, 25 or 26; pectoral rays 15 or 16; anterior gill rakers 23 to 25; posterior gill rakers 29 to 32. All counts based on five specimens from the Philippine Islands. A 165 mm. specimen has 17 upper and 18 lower teeth; a 270 mm. specimen has 18 upper and 20 lower teeth.

A 165 mm. specimen has a body depth which is contained 1.9 times in standard length, a snout length which is 4.4 in standard length, a caudal concavity which is 4.9 in standard length, an eye diameter which is 4.7 in head length, and a caudal spine length which is 3.7 in head length. A 270 mm. specimen has a body depth which is contained 2.3 times in standard length, a snout length which is 4.65 in standard length; a caudal concavity which is 4.4 in standard length, an eye diameter which is 5.7 in head length, and a caudal spine length which is 2.3 in head length.

Color (in alcohol) brown with numerous fine longitudinal pale lines on body which are about equal in width to the dark inter-

spaces; a black triangular or horseshoe-shaped mark on shoulder region, the upper end of which is just above upper end of gill opening and the lower end approaches the upper part of the axil of the pectoral fin (the width of the band forming this mark is about one-half the diameter of the pupil of the eye); sheath of caudal spine and a broad margin around socket of spine black; base of caudal fin abruptly pale; upper and lower lobes of caudal slightly lighter than dark brown center of fin; pectoral fins brown with a large pale yellow spot in outer upper part; dorsal, anal, and pelvic fins brown.

Fowler and Bean (1929) were in error in calling this species *Hepatus pyroferus* (Kittlitz). De Beaufort (1951) realized this and proposed the name *Acanthurus fowleri*. Fowler and Bean give two detailed color descriptions for the species (1929: 233).

Herre (1927: 411) included in *Acanthurus bariene* a 240 mm. specimen from Bantayan Island which had a violet-black line encircling an area on the shoulder more than twice the size of the eye, the caudal fin with a bluish white ring at the base and the central part black, and the caudal spine in a black spot. Probably he was describing a specimen of *A. fowleri*.

*Acanthurus fowleri* is unknown outside the Philippine-East Indian region.

***Acanthurus bariene* Lesson**

Fig. 2r, Pl. 3

*acanthurus bariene* Lesson (1830: 150) (Waigiou Island = Waigeo Island, New Guinea).

*Acanthurus nummifer* Cuvier and Valenciennes (1835: 234); Günther (1861: 338).

*Acanthurus kingii* Bennett, E. T. (1835: 119) (Port Praya).

*Rhombotides nummifer* Bleeker (1868: 297).

*Hepatus bariene* Jordan and Seale (1906: 352); Fowler and Bean (in part) (1929: 222) (Philippine Islands); Aoyagi (1943: 212, pl. 5, fig. 11, teeth only) (Okinawa).

*Acanthurus bariene* Herre (in part) (1927: 409,



*Acanthurus glaucopareius*, Gilbert Islands.



*Acanthurus achilles*, Hawaiian Islands.





pl. 1, fig. 2) (Philippine Islands); Smith (in part) (1949: 240) (Mozambique); de Beaufort (1951: 153).

Dorsal rays IX, 26 to 28; anal rays III, 25 or 26; pectoral rays 17 (fin ray counts based on six specimens from the Philippines); anterior gill rakers 19 to 23; posterior gill rakers 22 to 24 (raker counts from Philippine specimens); a 167 mm. specimen has 18 upper and 20 lower teeth; a 290 mm. specimen has 21 upper and 22 lower teeth.

Depth of body 1.9 to 2 in standard length; caudal concavity varying from 6.7 in standard length of 167 mm. specimen to 3.7 in standard length of 290 mm. specimen; longest dorsal ray varying from 4.9 in standard length of 167 mm. specimen to 5.3 in standard length of 290 mm. specimen.

Color (in alcohol) brown with numerous fine bluish gray longitudinal lines faintly visible on side of body; a round black spot, with a diameter about two-thirds that of eye, just above upper end of gill opening at level of eye (in some specimens this spot has a narrow pale blue margin); a dark brown area, about twice as high as maximum width of caudal spine, surrounding caudal spine; base of caudal fin abruptly pale, this pale region shading out a short distance on caudal lobes; central and posterior part of caudal fin brown; dorsal fin brownish yellow with narrow blue marginal and black submarginal lines, traces of dark longitudinal lines in outer part of fin, and a dark brown line at the base with a bluish gray line adjacent and distal to it; paired fins brown; opercular membrane dark brown.

H. W. Fowler and others have erred in applying the name *bariense* to the species *Acanthurus dussumieri* Cuvier and Valenciennes.

*Acanthurus bariense* appears to range from East Africa to the Riu Kiu Islands.

### *Acanthurus gahhm* (Forskål)

Fig. 2s, Pl. 3

*Cbaetodon nigro-fuscus* var. *Gahhm* Forskål

(1775: xiii, 64) (Red Sea).

*Cbaetodon Gahm* Linnaeus and Gmelin (1788: 1268).

*Acanthurus gahm* Cuvier and Valenciennes (1835: 219) (Red Sea and Mauritius); Günther (1861: 338); Klunzinger (1871: 506) (Red Sea); Günther (1873: 113, pl. 74) (Red Sea to the South Seas); Weber (1913: 318) (Saleyer, East Indies); Herre (1927: 411, pl. 12, fig. 2) (Philippine Islands); Herre (1936: 241) (Bora Bora and New Hebrides).

*Acanthurus gahhm* Bleeker (1858: 8) (Macassar, Celebes); de Beaufort (1951: 150) (East Indies).

? *Acanthurus gahmoides* Guichenot (1862: C. 8) (Réunion).

*Rhombotides gahhm* Bleeker (1865: 288) (Amboin, East Indies).

*Acanthurus (Rhombotides) gahm* Klunzinger (in part) (1884: 84) (Red Sea).

*Hepatus nigricans*. Jordan and Seale (1906: 351) (Samoa); Fowler (1923: 386) (Honolulu?); Fowler (1928: 272) (Oceania); Fowler and Bean (in part) (1929: 233) (Philippine Islands, East Indies, and Fiji).

*Acanthurus gahm nigricauda* Duncker and Mohr (1929: 75) (South Seas).

*Acanthurus nigricans*. Schultz (1943: 166) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 36, no. 612) (east coast of Africa south to Durban); Schultz and Woods in Schultz *et al.* (1953: 633, pl. 68) (Marshall and Mariana Islands); Harry (1953: 148) (Raroia, Tuamotu Archipelago).

*Hepatus nigrofuscus*, Hiyama (1943: 94, pl. 20, fig. 56).

Dorsal rays IX, 25 to 28; anal rays III, 23 to 26; pectoral rays 17; anterior gill rakers 20 or 21; posterior gill rakers 20 to 26 (raker counts from Philippine specimens); a 25 mm. specimen has 14 upper and 14 lower teeth; a 46 mm. specimen has 15 upper and 16 lower teeth; a 74 mm. specimen has 16 upper and 16 lower teeth; a 135 mm. specimen has 16 upper and 18 lower teeth; a 170 mm. specimen



has 17 upper and 19 lower teeth; a 195 mm. specimen has 18 upper and 20 lower teeth; a 226 mm. specimen has 19 upper and 22 lower teeth. The number of denticulations on the teeth decrease with age (see Table 16).

TABLE 15  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus gabbii* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS			
	25	26	27	28	23	24	25	26
Mauritius.....		1		1		1	1	
New Guinea.....				1			1	
Philippine Islands.	1	4	3		1	4	3	
Okinawa.....		1				1		
Palau Islands.....		3	4	1		1	4	3
Solomon Islands...	1						1	
Fiji Islands.....	1				1			
Mariana Islands...	1	1	2			1	2	1
Wake Island.....	2	2	1			3	1	1
Marshall Islands...		3	4			4	3	
Gilbert Islands...	1	7	4			4	7	1
Samoa Islands....		1	2	1			4	
Phoenix Islands...		1				1		
Society Islands...			1				1	

Caudal fin progressively more lunate with age, caudal concavity 6.5 in standard length of 76 mm. specimen and 3.6 in standard length of 237 mm. specimen; depth of body varying from 1.9 in standard length of 76 mm. specimen to 2.2 in 237 mm. specimen; snout length 4.3 to 4.5 in standard length; caudal spine 7.5 in head length of 76 mm. specimen, 4.5 in head length of 237 mm. specimen.

Color (in alcohol) brown, without lines on the body or spots on the head; a horizontal black band (usually rounded posteriorly) running backward from upper edge of gill opening (this band first appears in specimens about 55 to 60 mm. in standard length; on a 96 mm. specimen the length of the band is contained 7.6 times in the standard length; on a 237 mm. one the band is 5.5 in the standard length); a long lanceolate black line extending anteriorly from caudal spine (this line does not appear until a standard length

of about 100 mm. is attained; it becomes relatively longer in larger specimens and may reach half way from the caudal spine to the base of the pectoral fin on large specimens); caudal fin brown with prominent pale posterior margin (caudal fin of young entirely pale) which is broader in middle portion of fin, but narrows and disappears on caudal lobes (greatest width of posterior caudal margin of 96 mm. specimen contained 3.5 times in diameter of eye; greatest width of margin in 237 mm. specimen 4 in eye); base of caudal fin usually abruptly pale; outer one-third of pectoral fin pale (the inner half of this pale portion yellow in life); remaining fins brown.

Hiyama (1943: pl. 20, fig. 26) has figured the species [erroneously labelled *Hepatus nigrofuscus* (Forskål)] in the usual brown color form. Herre (1927: pl. 12, fig. 2) and Smith (1949: pl. 36, no. 612) have portrayed a bluish form with yellow dorsal and anal fins. Herre noted and figured an elongate dark blue spot on the nape anterior to the origin of the dorsal fin. He observed a living specimen in an aquarium which varied in color at different times from grayish blue to brownish gray. A specimen in the blue color phase with yellow fins was collected at Wake Island by W. A. Gosline and myself. It was not as light a blue as figured by Herre and by Smith but was

TABLE 16  
THE CHANGE IN THE NUMBER OF DENTICULATIONS  
ON THE TEETH OF SPECIMENS OF *Acanthurus gabbii*  
OF INCREASING STANDARD LENGTH

STANDARD LENGTH (mm.)	NUMBER ON UPPER TEETH	NUMBER ON LOWER TEETH
25	17	17
35	15-16	11
42	15-16	11-12
48	14-15	10-11
57	14	10
75	12-13	9
115	10-11	8
135	9-10	8
168	9	7-8
191	7-8	7-8

dark purplish gray in color. An elongate purple mark was clearly visible just in front of the origin of the dorsal fin.

Forskål (1775: 64) listed *gabhm* as a variety of *Chaetodon nigrofuscus*. His description is incomplete, but it applies to the species as here interpreted better than any other known Red Sea species of the genus. The color of the fish was given as black with the base of the caudal fin violet and the hind margin of the pectoral fin yellow.

Many recent authors have used the specific name *nigricans* for *Acanthurus gabhm*. *Chaetodon nigricans* Linnaeus, however, appears to be a species of *Naso*. The species described by Hasselquist (1757: 332), to which Linnaeus refers in his listing of *Chaetodon nigricans*, is definitely a *Naso*.

*Acanthurus gabhm* ranges from East Africa to Oceania. It is known from most of the island groups in Oceania. There is only one record from the Hawaiian Islands, that of Fowler (1923: 386) who used the name *Hepatus nigricans* for the species. He included no descriptive information with the record, and I have been unable to locate his specimen(s). One adult specimen of *Acanthurus olivaceus* from Johnston Island in the Bishop Museum was identified as *Hepatus nigricans* by Fowler. It is possible that the single Hawaiian record is a misidentification.

At Onotoa Atoll in the Gilbert Islands, adult *Acanthurus gabhm* were commonly seen around isolated coral heads in sandy regions of the lagoon, and the young were abundant in lagoon tide pools. No juvenile or adult individuals were observed in outer reef areas.

**Acanthurus maculiceps (Ahl)**

Fig. 2t, Pl. 3

*Hepatus maculiceps* Ahl (1923: 36) (Talassia, New Britain); Fowler (1928: 269); Fowler and Bean (1929: 240, fig. 13) (Philippine Islands and East Indies); Aoyagi (1943: 212, text fig. 53, pl. 4, fig. 10) (Okinawa). *Hepatus nigricans*. Fowler and Bean (in part) (1929: 233) (Celebes).

*Acanthurus maculiceps* de Beaufort (1951: 152).

Dorsal rays IX, 24 to 26, anal rays III, 23 or 24; pectoral rays 16; anterior gill rakers 19 to 23; posterior gill rakers 21 to 24 (raker counts from Philippine specimens); a 182 mm. specimen has 17 upper and 20 lower teeth; a 222 mm. specimen has 18 upper and 20 lower teeth.

TABLE 17  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus maculiceps* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	24	25	26	22	23	24
East Indies . . . . .		2	1		2	1
Philippine Islands . . . .	1	6	3	2	5	3
Gilbert Islands . . . . .	1	1			2	

Body depth 2 to 2.1 in standard length; caudal concavity varying from 5.7 in standard length of 182 mm. specimen to 3.5 in standard length of 228 mm. specimen; longest dorsal ray 5.4 to 5.5 in standard length; caudal spine 3.1 to 3.2 in head length.

Color (in alcohol) brown with numerous longitudinal paler brown lines on body (difficult to see on some specimens); a black bar, slightly greater than eye diameter in length, extending backward from upper edge of gill opening and often ending in a slight point; a second dark mark, less intense than the first and about the size of the pupil of the eye, just behind eye and often connected narrowly with the black bar; head with numerous pale spots (in average diameter slightly less than half the diameter of the pupil); all fins brown except for a vertical light gray band at base of caudal fin and pale yellow on outer third of upper six branched pectoral rays; nine dark brown longitudinal bands usually visible in dorsal fin; a very dark brown line, which is wider posteriorly, at base of dorsal fin; region around caudal spine dark brown.



The specimen shown in color in Plate 2 was collected from Binang Unang Island, Celebes, by the "Albatross" Expedition. It was misidentified as *Hepatus nigricans* by Fowler and Bean (1929: 236).

*Acanthurus maculiceps* is known at the present time only from the East Indies, Philippines, Riu Kiu Islands, and the Gilbert Islands.

A 193 mm. specimen collected by the author at Onotoa Atoll in the Gilbert Islands was speared at a depth of about 20 feet on the coralliferous terrace of the outer reef.

*Acanthurus auranticavus* Randall

Figs. 2*u*, 19

*Hepatus nigrofuscus*. Fowler and Bean (in part) (*non* Forskål) (1929: 237) (Philippine Islands and East Indies).

*Holotype*.—United States National Museum Number 136194, Atulayan Island, Lagonoy Gulf, east coast of Luzon, June 17, 1909, "Albatross" Expedition, 203 mm. in standard length.

*Paratypes*.—U.S.N.M. No. 163823, Mansalay, southeast Mindoro, June 4, 1908, "Albatross" Expedition, 144 mm. in standard length; U.S.N.M. No. 136202, Danawan Island, Borneo, September 27, 1909, "Albatross" Expedition, 208 mm. in standard length; U.S.N.M. No. 136188, Buang Bay, Talajit Island (between Samar and Masbate, Philippine Islands), March 15, 1909, standard length 217 mm. (to be sent to the British Museum); Stanford Mus. No. 47695, Atulayan Island, Lagonoy Gulf, Luzon, June 17, 1909, "Albatross" Expedition, two specimens, 179 and 207 mm. in standard length.

*Description* (data in parentheses are the extremes in counts and measurements for all the paratypes).—Dorsal rays IX, 26 (25 or 26); anal rays III, 24 (23 or 24, usually 24); pectoral rays 16 (16 or 17); anterior gill rakers 21 (20 to 23); posterior gill rakers 25 (24 to 28); scales from gill opening to posterior end of caudal spine 217 (195 to 233); number of upper teeth 18 (18 or 19); number of lower teeth 18 (18 to 20).

The following measurements are propor-

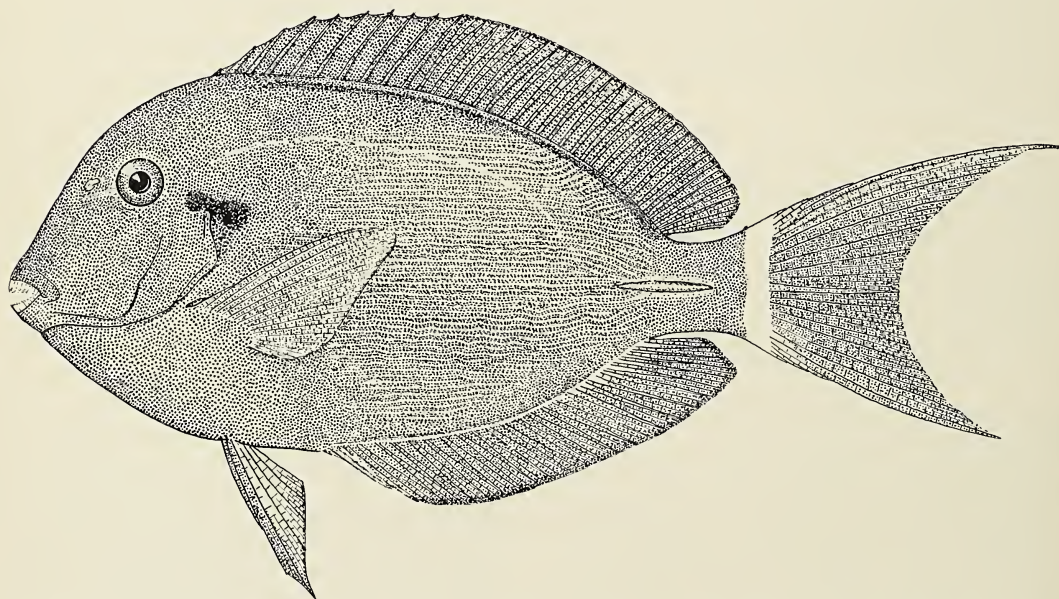


FIG. 19. *Acanthurus auranticavus*, n. sp. Drawing of holotype by Aime M. Awl, United States National Museum.

tions of the standard length: depth of body 2.09 (2.03 to 2.14); length of head 3.98 (3.57 to 3.89); length of snout 4.84 (4.58 to 4.94); length of pectoral fin 3.69 (3.35 to 3.78); length of pelvic fin 4.06 (4.12 to 4.60); pelvic spine 7.65 (6.55 to 8.62); ninth dorsal spine 6.67 (5.34 to 7.24); longest dorsal ray 5.80 (5.24 to 6.50); third anal spine 8.84 (7.39 to 9.44); longest anal ray 6.34 (5.24 to 6.26); caudal concavity 4.41 (4.21 to 6.75).

The following measurements are proportions of the head length: greatest diameter of eye 3.92 (3.51 to 4.53), width of interorbital space 2.76 (2.82 to 3.22), least depth of caudal peduncle 2.25 (2.33 to 2.76), length of caudal peduncle spine 2.22 (2.47 to 4.46), distance from base of upper lip to distal ends of upper teeth 5.67 (6.14 to 6.99).

Color in life of specimens including the holotype (identified by "Albatross" field number) from Fowler and Bean (1929: 238). "Dark brown, sometimes with slate; on fading side shows narrow brown lines with blue-white interspaces as in *Ctenochaetus strigosus*. Breast from pectoral base downward washed orange brown. Caudal spine with bright orange socket. Orange blotch before and behind pupil. Dull obscure orange stripe from eye through nostrils across frontal region. No shoulder blotch. Dorsal slate-gray or almost black basally, and in alcohol few narrow bars appear on hind terminal portion. Anal like dorsal, without dark base and edge narrowly bright blue. Caudal slate, without white tip but white band across base. Pectoral slate, tips somewhat olive yellow. Ventral slate, with slight yellowish dash at tips of last rays."

Color in life of paratype from Buang Bay, Talajit Island from Fowler and Bean (1929: 240): "Body very finely striped with purplish blue and olive. Front and side of head brown becoming blackish on vertical flap. Very short dark blotch behind upper angle of gill opening. Breast mostly dusky, also with orange shades. Fins dull violaceous, dorsal edge somewhat purplish with submarginal translucent bar; anal margin bright purple. White

band across caudal base. Caudal spine with orange socket. Paired fins olive or black, without marks or color variation."

Color (in alcohol) brown with about 55 slightly wavy bluish gray longitudinal lines on body (faded in some specimens) which tend to converge posteriorly on caudal spine; a dark brown bar (1.3 eye diameters in length, in the holotype) on shoulder region which is restricted in width as it passes upper end of gill opening; shoulder bar tilted downward so that a line bisecting it passes from the center of the eye to the base of the 18th anal ray; caudal fin yellowish brown with a chalky white bar at base; dorsal fin yellowish brown with a dark brown band at base (broader posteriorly) and an indistinct narrow dark outer margin; anal fin grayish brown with a faint bluish white band at base and an indistinct narrow dark outer margin; pectoral fins yellowish brown; pelvic fins grayish brown; socket of caudal spine and a margin around the socket as wide as half the width of the spine orange-brown.

The shoulder blotch in this species is not black as in *Acanthurus gabbem* and *Acanthurus maculiceps* but dark brown or orange-brown. On some specimens it can be perceived only with difficulty.

*Acanthurus auranticavus* appears to be most closely related to *Acanthurus maculiceps* from which it differs primarily in shape and color of the shoulder blotch and lack of pale spots on the head; there is no large pale area on the pectoral fin, nor are there prominent bands in the dorsal and anal fins. Also the posterior gill rakers are more numerous in *A. auranticavus*.

The species is named *auranticavus* in reference to the orange socket of the caudal spine.

I have seen specimens only from the Philippine Islands and the East Indies.

#### *Acanthurus grammoptilus* Richardson

Figs. 2*v*, 20

*Acanthurus grammoptilus* Richardson (1843:



176) (Port Essington, N. Australia); Bleeker (1855: 11) (van Diemensland, N. Australia); Günther (1861: 335); Macleay (1878: 354) (Port Darwin, N. Australia); Macleay (1881: 528).

*Hepatus nigrofuscus*. Fowler and Bean (in part) (1929: 237) (Mansalay, Mindoro, Philippine Islands).

Dorsal rays VIII or IX (one specimen with VIII, four with IX), 25 or 26; anal rays III, 23 or 24; pectoral rays 16 or 17; anterior gill rakers 16 to 18; posterior gill rakers 21 to 23; a 93 mm. specimen has 14 upper and 18 lower teeth; a 205 mm. specimen has 18 upper and 20 lower teeth; a 245 mm. specimen has 18 upper and 20 lower teeth. All counts based on five specimens from Arnhem Land, northern Australia.

Body depth varying from 1.9 in standard length of a 93 mm. specimen to 2.5 in a 245 mm. specimen; caudal concavity 6.3 to 7.7 in standard length; head length 3.4 to 3.7 in standard length; pectoral fin 3.3 to 3.4 in standard length; pelvic fin 3.6 to 4.3 in standard length; length of snout 4.4 to 4.5 in standard length; length of longest dorsal ray 5 to 5.5 in standard length; interorbital space 3.1 to 3.2 in head length; diameter of eye 3.5 in head length of 93 mm. specimen, 5.2 in head length of 245 mm. specimen.

Color (in alcohol) of 245 mm. Arnhem

Land specimen brown with narrow light brown longitudinal undulating lines faintly visible on the sides; caudal spines surrounded by a very dark brown area which extends anterior to the spine a distance greater than one eye diameter; base of caudal fin white; rest of fin brown except posterior margin which is narrowly pale; pectoral fin with outer one-third pale, basal two-thirds brown; a light brown area behind eye, outlined by a narrow dark line; five acuminate light brown bands projecting forward from eye and separated by dark brown lines; remainder of head brown with pale brown spots; dorsal and anal fins brown with a narrow dark brown border and traces of narrow dark brown bands in distal part of soft portion of these fins; five narrow dark brown longitudinal bands barely visible in spinous part of dorsal fin; a dark brown band at base of dorsal fin; pelvic fins brown; opercular membrane dark brown. At the upper end of the gill opening there is a faint dark brown elongate blotch which extends posteriorly a distance almost equivalent to an eye diameter.

The 93 mm. Arnhem Land specimen differed from the above in having fewer lines on the body, a wider pale posterior border to the caudal fin (about one-third pupil diameter in width), a narrower dark margin around the caudal spine which does not extend anterior to spine, more prominent bands in the dorsal and anal fins, and no dark brown band at the base of the dorsal fin. The color of this specimen in life (from field notes of R. R. Miller who collected the Arnhem Land specimens in 1948) was brown with a white band across the base of the caudal fin and a white posterior margin to the fin. Rust-colored spots, blotches, and wavy lines were present on the head and nape; the pectoral fin was yellowish, and there was a narrow blue margin on the anal fin.

A. C. Wheeler has kindly provided information on two of Richardson's specimens (actually half skins) of *A. grammoptilus*, the larger of which (labelled Coral Bay, Port Essington, Nov. 1840, No. 13 and bearing

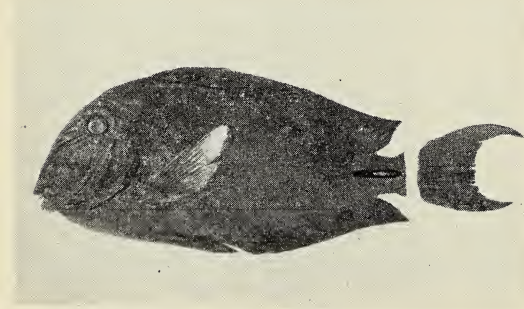


FIG. 20. *Acanthurus grammoptilus*. 245 mm. specimen, Arnhem Land, Australia. Photograph of preserved specimen by Frederick M. Bayer, United States National Museum.

British Museum No. 1843.6.15.38) is 191 mm. in standard length and evidently formed the basis for Richardson's description. Günther (1861: 335) listed these skins as types. I designate the larger as lectotype.

Richardson's description plus data from Wheeler to the effect that the larger specimen has a depth of 86 mm., 18 or 19 teeth in the jaws, inconspicuous dark streaks in the dorsal and anal fins, a dark area around the caudal peduncle spine, faint longitudinal lines on the body, no black spot at axil of dorsal or anal fins (Günther was in error in reporting these), and a pectoral fin which is darker basally leave no doubt that the species is valid and that the Arnhem Land specimens which I examined are the same.

A 204 mm. specimen in the United States National Museum from Mindoro, Philippine Islands (misidentified as *Hepatus nigrofuscus* by Fowler and Bean, 1929) appears to be *Acanthurus grammoptilus*. A color note given by Fowler and Bean (1929: 239, "Albatross" No. 6167) is as follows: "No trace of black shoulder mark. More or less orange below caudal spine. Dorsal and anal edged blue. Caudal with very narrow pale edge behind. Pectoral edge yellow." In spite of word to the contrary, there is a faint dark brown shoulder mark. It extends posteriorly from the upper edge of the gill opening a distance equivalent to about one and one-half eye diameters. The mark is not black and could have been overlooked in the field. Surrounding the caudal spine and projecting anterior to it is a reddish brown area. This area is rounded anteriorly like the comparable dark brown region in front of the caudal spine of the large Arnhem Land specimen. The outer one-fourth of the pectoral fin is pale. There is a dark brown band at the base of the dorsal fin and a narrow dark brown margin. The margin of the anal fin is dark blue.

Counts of this specimen are: D IX, 26; A III, 24; P 17; anterior gill rakers 22; posterior gill rakers 24; 17 upper teeth; 20 lower teeth (the end ones tiny).

An Arnhem Land specimen of the same length as the Philippine one provided a basis for comparison of proportional measurements (although the Philippine specimen is a male with the typical highly convex forehead and the Arnhem Land one a female). The Philippine fish has a shorter body (depth 2.2 in standard length, instead of 2.4), a shorter head (3.9 in standard length instead of 3.4), a shorter snout, a longer caudal spine, and a smaller eye. With so few specimens available and the differing sex of the two in question, it is difficult to assess these differences. Even if it could be demonstrated that the measurements of the Philippine specimen are not within the range of variability of Australian *A. grammoptilus*, the problem of deciding whether the differences are subspecific and reflect the geographic separation of the Philippines from Australia would still remain unsolved. In view of the similarity in color pattern, I prefer to regard the Philippine and Arnhem Land specimens as conspecific.

McCulloch (1918) erroneously used the name *grammoptilus* for the species *Acanthurus dussumieri*. Fowler and Bean (1929) applied the name to specimens of *A. dussumieri* and *A. xanthopterus*.

*Acanthurus doreensis* Cuvier and Valenciennes may be a specimen of *A. grammoptilus* with abnormal fin ray counts (see discussion of this doubtful species on page 226).

***Acanthurus dussumieri* Cuvier  
and Valenciennes  
Figs. 1*b*, 2*w*, Pl. 3**

*Acanthurus Dussumieri* Cuvier and Valenciennes (1835: 201) (Mauritius).

*Acanthurus undulatus* Cuvier and Valenciennes (1835: 205) (Indian Ocean); Günther (1861: 335).

*Acanthurus Lamarrii* Cuvier and Valenciennes (1835: 236) (Mauritius).

*Acanthurus dussumieri* Günther (1861: 335); Günther (1873: 112, pl. 14, fig. 3) (Hawaiian Islands); Sauvage (1891: 337) (Ma-



dagascar); Steindachner (1901: 493) (Honolulu); Jordan and Jordan (1922: 65) (Hawaiian Islands); Herre (1927: 425, pl. 14, fig. 3) (Philippine Islands); de Beaufort (1951: 155).

*Acanthurus matoides* Var. *b.* Playfair in Playfair and Günther (1866: 56) (Zanzibar).

*Rhombotides Dussumieri* Bleeker in Bleeker and Pollen (1874: 96) (Mauritius).

*Rhombotides Lamarrii* Bleeker in Bleeker and Pollen (1874: 96) (Mauritius).

*Teuthis dussumieri* Jordan and Evermann (1902: 357) (Formosa); Jenkins (1903: 477) (Honolulu).

*Hepatus dussumieri* Jordan and Evermann (1905: 390, fig. 169) (Hawaiian Islands); Jordan and Seale (1906: 351); Aoyagi (1943: 214, text fig. 54, pl. 5, fig. 14) (Riu Kiu Islands).

*Teuthis grammoptilus*, McCulloch (1918: 92, pl. 28) (Clarence River and Masthead Island, New South Wales).

*Hepatus bariene*. Fowler (1928: 270, pl. 31, fig. C) (Hawaiian Islands); Fowler and Bean (in part) (1929: 222) (Philippine Islands).

*Hepatus grammoptilus*. Fowler and Bean (in part) (1929: 225) (Philippine Islands and East Indies).

*Acanthurus bariene*. Smith (in part) (1949: 240, pl. 33, no. 613) (east coast of Africa south to Delagoa Bay).

Dorsal rays IX (one specimen found with VIII), 25 to 27; anal rays III, 24 to 26; pectoral rays 16 or 17 (usually 17); anterior gill rakers 22 to 26; posterior gill rakers 23 to 27 (see Table 20); a 48 mm. specimen has 14 upper and 14 lower teeth; a 61 mm. specimen has 16 upper and 18 lower teeth; a 94 mm. specimen has 17 upper and 18 lower teeth; a 132 mm. specimen has 19 upper and 20 lower teeth; a 325 mm. specimen has 20 upper and 22 lower teeth.

Depth of body (in specimens 110 to 214 mm. in standard length) about 1.9 in standard length (nearly 2.1 in specimens greater than

TABLE 18  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus dussumieri* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	25	26	27	24	25	26
Mauritius.....		3			3	
Philippine Islands....	2	8	2	1	10	1
Formosa.....		2			2	
Okinawa.....		1		1		
Hawaiian Islands.....	4	10	3	2	10	5

300 mm. in standard length); caudal concavity varies from 14 in standard length in a 110 mm. specimen to about 7 to 9 in specimens 167 to 214 mm. in standard length to about 5 or less in specimens over 300 mm. in standard length; length of snout 4.2 to 4.6 in standard length; length of caudal spine 3 to 5 in head length (relatively longer in larger specimens); diameter of eye 3.4 in head length of 110 mm. specimen, 4 in head length of 214 mm. specimen, and 4.7 in 300 mm. specimen.

Color (in alcohol) light brown with numerous, narrow, longitudinal, slightly wavy, purplish or bluish gray lines on body; similar but broader and more irregular lines on head (these and the body lines may fade in preserved specimens); a pale brown (yellow in life) band about as wide as the pupil diameter extending anterodorsally from eye and often meeting a comparable band from other side midway in interorbital space; posterior edge of eye margined with a pale brown (yellow in life) area; caudal spine largely covered by a cream sheath; socket of caudal spine surrounded by a black area about three times as high as maximum width of caudal spine; caudal fin light brown basally and on lobes, darker in major median portion (deep blue in life) with numerous small brownish black spots; dorsal and anal fins of adults light yellowish brown (yellow in life) with traces of about two or three longitudinal dark lines posterodistally (absent in large adults); a

pale bluish gray line at base of dorsal and anal fins; pectoral fins light yellowish brown; pelvic fins brown; opercular membrane black.

*Acanthurus dussumieri* has at times been confused with *A. xanthopterus* and *A. mata*. Adults of *A. dussumieri* may be readily recognized by the black spots on the caudal fin, the white caudal spine sheath and black area around the caudal spine, lack of a distinct series of longitudinal dark bands from base to margin of dorsal and anal fins, and the presence of purplish longitudinal lines on the body. In small specimens, however, there are longitudinal dark bands from base to margin of the dorsal and anal fins (eight in the soft dorsal of a 110 mm. specimen), the spots on the tail are less distinct or absent, and the sheath of the caudal spine is not as contrastingly pale. The lines on the body are broader and hence fewer in number; in fresh specimens the linear pattern on the body remains as the best color character for separating *A. dussumieri* from the other two species, but, as mentioned, the lines may fade on preserved specimens. The larger eye and higher gill raker counts of *A. dussumieri* are then very helpful in distinguishing this species.

I have seen specimens of *A. dussumieri* or know of definite records of this species from the east coast of Africa, islands in the Indian Ocean, Australia, East Indies, Formosa, Philippine Islands, Riu Kiu Islands and probably also southern Japan, and the Hawaiian Islands. The latter group of islands represents the sole locality for the species in Oceania. If this were ultimately found to be the true range of the species, it would be supporting evidence that pioneer fishes of the Hawaiian Archipelago arrived via the extension of the Kuroshio Current and the North Pacific Current from islands to the west of Hawaii, rather than from reefs and small islands south of Hawaii by way of a branch of the north equatorial current as postulated by Herre (1940). I do not advocate, however, that such an indication from one or even several species should form the basis for the assumption that

the entire Hawaiian fish fauna had such a mode of origin.

Jordan and Seale (1906: 351) stated that *Hepatus dussumieri* is the commonest species of the genus about the Hawaiian Islands. In the same work these authors listed *Hepatus sandvicensis* (= *Acanthurus triostegus sandvicensis*) as the most abundant species of the genus about Hawaii. I concur in their latter statement. Although *Acanthurus dussumieri* is a very common species in the Hawaiian Islands, it is probably exceeded in abundance by *Acanthurus nigrofusus* and perhaps other species as well as *Acanthurus triostegus*. It occurs both in bays and in exposed reef areas.

*A. dussumieri* is one of the three largest species of *Acanthurus*; it reaches a standard length of at least 400 mm.

#### *Acanthurus xanthopterus* Cuvier and Valenciennes

Fig. 2x, Pl. 3

*Acanthurus xanthopterus* Cuvier and Valenciennes (1835: 215) (Seychelles); Valenciennes (1837: pl. 71, fig. 2); Cantor (1849: 1191, pl. 4) (Pinang, Malaya).

*Acanthurus matoides*. Bleeker (1850a: 12) (Batavia, Java); Günther (1861: 330) (East Indies and Fiji Islands); Day (1865: 126) (seas of India); Playfair in Playfair and Günther (1866: 56) (Zanzibar) (as Variety a); Klunzinger (1871: 508) (Red Sea); Day (1876: 205) (seas of India); Day (1889: 141); Jordan and Snyder (1907: 217) (Hawaiian Islands); Jordan and Jordan (1922: 65) (Honolulu); Vinciguerra (1926: 567) (Sarawak, Borneo); Herre (1927: 430, pl. 16, fig. 3) (Honolulu and Philippine Islands); Herre (1936: 243) (Tahiti and Solomon Islands); de Beaufort (1951: 156) (East Indies).

*Rhomboides matoides* Bleeker (1863b: 235) (Ternate, East Indies).

? *Acanthurus matoides* Kner (1865–67) (India).

*Acanthurus blochii*. Günther (1873: 109, pl. 69, fig. B) (Indo-Pacific); Waite (1897: 188) (Funafuti, Ellice Islands).



*Teuthis crestonis* Jordan and Starks in Jordan (1895: 485, pl. 47) (Mazatlan, Mexico); Jordan and Evermann (1898: 1692); Jordan and Evermann (1900: pl. 256, no. 628); Gilbert and Starks (1904: 151) (Panama Bay).

*Teuthis mata*. Seale (1901: 107) (Guam).

*Teuthis argenteus*. Jordan and Fowler (1902: 553) (Okinawa and Japan).

*Teuthis güntberi* Jenkins (1903: 477, fig. 29) (Honolulu).

*Teuthis xanthopterus* Jenkins (1903: 477) (Hawaiian Islands).

*Hepatus matoides*. Jordan and Evermann (1905: 387) (Honolulu); Jordan and Seale (1906: 352) (Samoa); Jordan and Seale (1907: 34) (Philippine Islands).

*Hepatus guntheri* Jordan and Evermann (1905: 388, fig. 168).

*Hepatus xanthopterus* Jordan and Evermann (1905: 389) (Honolulu).

*Hepatus aquilinus* Jordan and Seale (1906: 353, fig. 66) (Apia, Samoa).

? *Teuthis guentheri* Bamber (1915: 482) (Red Sea).

*Hepatus crestonis* Snodgrass and Heller (1905: 403) (Cocos Island off Costa Rica); Fowler (1916: 411) (Panama Bay).

*Acanthurus umbra*. Jordan and Jordan (in part) (1922: 65) (Hawaiian Islands).

*Teuthis nigrofuscus*. Barnard (1927: 779) (Natal coast, Africa).

*Hepatus fuliginosus*. Fowler (1927: 17) (Fanning Island, Line Islands); Fowler (in part) (1928: 266, pl. 31, fig. B) (Oceania); Fowler and Bean (in part) (1929: 211) (Hawaiian Islands); Fowler (1934: 480) (Durban, Natal); Fowler (1938: 102, 202, 211, 230) (Takaroa in the Tuamotu Archipelago, Christmas and Fanning Islands, and Honolulu).

*Acanthurus crestonis* Meek and Hildebrand (1928: 782) (west coast of Panama).

? *Hepatus nigrofuscus*. Fowler (1928: 267) (Christmas Island, Oceania).

*Hepatus elongatus*. Fowler and Bean (in part) (1929: 213) (Hawaiian Islands and Samoa).

*Hepatus bariene*. Fowler and Bean (in part) (1929: 222) (Hawaiian Islands).

*Acanthurus grammoptilus*. Fowler and Bean (in part) (1929: 225) (Philippine Islands and East Indies).

*Acanthurus fuliginosus*. Schultz (1943: 166) (Phoenix and Samoa Islands); Smith (1949: 240, pl. 33, no. 611) (east coast of Africa south to Durban); Schultz and Woods in Schultz *et al.* (1953: 637) (Guam).

*Teuthis fuliginosus*. Fowler (1949: 102).

Dorsal rays IX (two specimens were found with VIII), 25 to 27; anal rays III, 23 to 25; pectoral rays 16 or 17 (usually 17); anterior gill rakers 16 to 24; posterior gill rakers 17 to 22 (see Table 20); a 37 mm. specimen has 12 upper and 14 lower teeth; a 59 mm. specimen has 13 upper and 15 lower teeth; a 97 mm. specimen has 15 upper and 16 lower teeth; a 126 mm. specimen has 17 upper and 18 lower teeth; a 196 mm. specimen has 18 upper and 20 lower teeth; a 320 mm. specimen has 18 upper and 21 lower teeth.

TABLE 19  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus xanthopterus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	25	26	27	23	24	25
Durban, S. Africa . . . . .		3	2		2	3
Red Sea . . . . .		1			1	
Mauritius . . . . .		1	1		1	1
East Indies . . . . .		2	2		2	2
Philippine Islands . . . . .	1	4	2	1	3	3
Solomon Islands . . . . .	1	1			2	
Mariana Islands . . . . .	1	5	1		7	
Gilbert Islands . . . . .		1	1		1	1
Phoenix and Samoa Islands . . . . .		5	2		5	2
Line Islands . . . . .		3			1	2
Jarvis Island . . . . .		1				1
Hawaiian Islands . . . . .	2	3	2		6	1
Galapagos Islands . . . . .		1				1
W. Mexico and W. Panama . . . . .	2	5	1		4	4

Body depth varies from 1.95 in standard length of a 127 mm. specimen to 2.25 in a 423 mm. specimen; caudal concavity 7 in standard length of a 127 mm. specimen, 5 in standard length of a 196 mm. specimen, and 4.6 in a 320 mm. specimen; length of snout 4.8 in standard length of 127 mm. specimen, 4.95 in 196 mm. specimen, and 5.3 in 423 mm. specimen; diameter of eye 3.9 in head length of 127 mm. specimen, 4.1 in 173 mm. specimen, 4.4 in 196 mm. specimen, 4.7 in 310 mm. specimen, and 5.6 in 415 mm. specimen; length of caudal spine 5.5 in head length of 127 mm. specimen, 5 in 173 and 196 mm. specimens, 4.4 in a 310 mm. specimen; longest dorsal ray 4.4 in standard length of 127 mm. specimen, 5 in standard length of 196 mm. specimen, and 5.7 in standard length of a 320 mm. specimen.

A 196 mm. specimen of *A. xanthopterus* was speared by the author in the lagoon at Tarawa Atoll, Gilbert Islands, at a depth of 39 feet and provided the following description of the life colors: while the fish was still alive, the body color changed back and forth from uniform purplish gray to a color phase in which extremely irregular dark gray lines (about two scales in width) alternated with light blue-gray lines of about the same width; extreme posterior part of caudal peduncle and base of caudal fin dull white; remainder of caudal fin purplish gray; dorsal and anal fins yellowish gray basally, shading to dull yellow distally, with four longitudinal broad blue bands; a narrow bluish gray band at base of dorsal and anal fins; outer margin of dorsal and anal fins narrowly black; basal two-thirds of pectoral fin dusky, outer one-third yellow except extreme distal part which is hyaline; pelvic rays purplish gray, membranes dusky yellow; lower two-thirds of eye margined with diffuse yellow; a region of dull yellow extending directly anterior from eye a distance equivalent to about one eye diameter; a lesser posterior extension of dull yellow from lower corner of eye.

Preserved specimens are usually a uniform

grayish brown; only occasional specimens retain the tortuous line pattern on the body. The bands in the dorsal and anal fins may fade.

The most important color characters of *A. xanthopterus*, for separating the species from *A. mata* and *A. dussumieri*, are the number of longitudinal bands in the dorsal and anal fins, the lack of narrow, nearly straight, longitudinal lines or rows of spots on the body, the lack of a black region around the caudal spine (although the region around the spine may be slightly darker than the color of the body), and (in adults) the abrupt pale color of the outer one-third of the pectoral fin. There are no small black spots on the caudal fin, no whitish caudal spine sheath, and no definite pale band which crosses or nearly crosses the interorbital space, all characteristic color markings of *A. dussumieri*.

Apart from color, *A. xanthopterus* is most distinctive in its possession of a small caudal spine, small eye (not useful in separation from *A. mata*), and low gill raker counts (see Table 20).

In Fowler and Bean (1929: 227) there is a color description of specimens bearing "Albatross" numbers 8509 and 8510 which these authors identified as *Hepatus grammoptilus*. These specimens and probably others are *Acanthurus xanthopterus*. The description of the color of specimens with the numbers 7803, 7804, and 7806, however, apply to *Acanthurus dussumieri*.

The specific names most commonly used for *A. xanthopterus* are *matoides* and *fuliginosus*. *Acanthurus matoides* Cuvier and Valenciennes is a synonym of *Acanthurus nigrofuscus*. *Acanthurus fuliginosus* Lesson was described as a uniform brown fish with a blue line on the chin. It is very unlikely that this species is the same as *A. xanthopterus* (see page 160).

Günther (1873: 109, pl. 69, fig. B) misidentified *A. xanthopterus* as *Acanthurus blochii*. *Acanthurus blochii* Cuvier and Valenciennes is probably a synonym of *Acanthurus mata* (Cuvier).



Fowler and Bean (1929: 214) placed *Hepatus aquilinus* Jordan and Seale in the synonymy of *Hepatus elongatus*. I examined the type of *H. aquilinus*, and it is a moderately large specimen of *Acanthurus xanthopterus*.

I am unable to distinguish *Acanthurus cresson* (Jordan and Starks) of the western coast of Mexico and Central America from *Acanthurus xanthopterus*; thus I have placed the former in the synonymy of the latter.

The type of *Acanthurus xanthopterus*, a 162 mm. specimen, is in the Paris Museum (No. 162).

*A. xanthopterus* is probably the largest species of *Acanthurus*. It may exceed 500 mm. in standard length. It occurs commonly in bays and lagoons, but may also be taken in outer reef areas. At least in the adult stage it appears to be more characteristic of deeper water than

most surgeon fishes. Trap fishermen in the Hawaiian Islands refer to the species as deep water *pualu*; they call *A. mata* merely *pualu*. *A. xanthopterus* is a wide-ranging species. It is known from East Africa to West Mexico.

**Acanthurus mata** (Cuvier)  
Figs. 1d, 2y, Pl. 3

- ? *Chaetodon nigricans*. Bloch (1787: 184, pl. 203).
- ? *Acanthurus nigricans*. Bloch and Schneider (1801: 211) (Arabian Sea).
- ? *Acanthurus nigricans*. Rüppell (1828: 57) (Red Sea).
- Chaetodon meta* Cuvier (1829: 224) (after Russell, error for *mata*).
- Acanthurus mata* Cuvier and Valenciennes (1835: 202); Schultz and Woods in Schultz *et al.* (1953: 639) (Marshall Islands).

TABLE 20  
VARIATION IN GILL RAKER COUNTS OF SPECIMENS OF *Acanthurus dussumieri*, *Acanthurus xanthopterus*, AND *Acanthurus mata* FROM DIFFERENT LOCALITIES

SPECIES AND LOCALITY	ANTERIOR GILL RAKERS												POSTERIOR GILL RAKERS													
	16	17	18	19	20	21	22	23	24	25	26	17	18	19	20	21	22	23	24	25	26	27				
<i>A. dussumieri</i>																										
Mauritius . . . . .									1										1							
Philippine Islands.							1	2	1	1								1	2		2					
Hawaiian Islands..								3	3		1								2	3	1	1				
<i>A. xanthopterus</i>																										
Durban, S. Africa.					1				1							1	1									
Red Sea . . . . .			1												1											
Mauritius . . . . .		1					1					1				1										
Philippine Islands.		1	4	1											1	3	2									
Solomon Islands..				1			1								1	1										
Mariana Islands...	1	2	3												4	1	1									
Gilbert Islands....			1			1									1	1										
Phoenix and																										
Samoa Islands...		1	3										1			1		1								
Line Islands . . . . .		2		1												1	2									
Hawaiian Islands..		1	3	3	1	1	1					1	1	2	4	2										
Galapagos Islands.						1									1											
W. Mexico and																										
W. Panama . . . . .		1	2		2		1						1	3	1	1										
<i>A. mata</i>																										
Durban, S. Africa.					1													1								
Mariana Islands...						1																				
Marshall Islands..					1	1													1		1					
Wake Island.....							2														1					
Tuamotu																										
Archipelago . . . . .					1																					
Hawaiian Islands..					2	4	9	3		1								5	5	8	1					

*Acanthurus rasi* Cuvier and Valenciennes (1835: 203) (Pondichéry, India).

? *Acanthurus Blochii* Cuvier and Valenciennes (1835: 209) (Mauritius).

*Acanthurus nigro-fuscus*. Günther (1861: 331) (Ceylon and Amboin, East Indies).

*Acanthurus blochi* Streets (1877: 68) (Harbor of Honolulu).

*Acanthurus umbra*. Jordan and Jordan (in part) (1922: 65) (Hawaiian Islands); Schultz (1943: 165) (Tutuila Island, Samoa Islands).

? *Hepatus mata* Fowler (1928: 267) (Society Islands).

*Hepatus bariene*. Fowler and Bean (in part) (1929: 222) (Philippine Islands).

? *Teuthis mata* Fowler (1949: 102).

*Acanthurus sp. two* Harry (1953: 150) (Raroia, Tuamotu Archipelago).

*Acanthurus lineolatus*. Smith (in part) (1949: 240, pl. 33, no. 609) (east coast of Africa south to Durban).

Dorsal rays IX, 25 to 27; anal rays III, 24 or 25; pectoral rays 17; anterior gill rakers 20 to 25; posterior gill rakers 23 to 26 (see Table 20); a 47 mm. specimen has 14 upper and 14 lower teeth; an 84 mm. specimen has 16 upper and 16 lower teeth; a 101 mm. specimen has 16 upper and 18 lower teeth; a 153 mm. specimen has 18 upper and 19 lower teeth; a 203 mm. specimen has 18 upper and 20 lower teeth; a 247 mm. specimen has 20 upper and 20 lower teeth.

Depth of body 1.9 to 2.1 in standard length; caudal concavity varies from 10 in standard length of a 151 mm. specimen to 8.2 in a 191 mm. specimen, and to 6.2 in a 292 mm. specimen; length of snout 4.3 to 4.5 in standard length; eye diameter 3.1 in head length of 47 mm. specimen, 4.2 in head length of 151 mm. specimen, and 5 in head length of 292 mm. specimen; length of caudal spine 3 to 4.4 in head length.

Color (in alcohol) brown (the rows of small spots on the sides are usually lost in preservative); base of caudal fin abruptly pale, remainder of fin brown (dark blue in life with about six indistinct, vertical, slightly wavy, dark lines); dorsal fin with eight or nine narrow longitudinal dark bands, and anal fin with five or six similar bands (the bands in the fins are often not visible in preserved specimens); pectoral fins entirely brown; pelvic fins brown; dark brown to black region around caudal spine about twice as high as maximum width of spine; the most prominent marking on head in life is an elongate yellow spot (about half the size of the eye) which extends posteriorly and slightly upward from lower edge of eye; this is usually lost in preservative.

*A. mata* is distinct from *A. xanthopterus* in having eight or nine instead of four or five longitudinal dark bands in the soft portion of the dorsal fin, a uniform brown pectoral fin (the outer one-third of the pectoral fin of *A. xanthopterus* is pale), a more definite dark area around the caudal spine, a larger caudal spine, and higher gill raker counts.

Adult *A. mata* may be distinguished from adult *A. dussumieri* by lacking black caudal spots, white caudal spine sheath, and a pale transverse band on the interorbital, and having numerous longitudinal bands in the dorsal and anal fins. Fresh specimens of subadult *mata* may be best distinguished from *A. dussumieri* of about the same size (which may have eight or nine bands in the dorsal fin and five or six in the anal like *mata*) by the linear pattern of the body. Lines of small pale spots occur on *A. mata*; the lines on the body

TABLE 21  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus mata* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	25	26	27	23	24	25
Durban, S. Africa . . . .		1				1
Mariana Islands . . . . .	1				1	
Marshall Islands . . . . .	1	1			2	
Wake Island . . . . .			1			1
Tuamotu Archipelago . . .		1			1	
Hawaiian Islands . . . . .	4	9	2	1	12	2



of *A. dussumieri* are unbroken. On preserved specimens the body color of either species may be uniform brown; the larger size of the eye of *dussumieri* is then the best means of separation.

When viewed underwater, *A. mata* appears almost black except for the base of the caudal fin which is usually white. The degree of whiteness of the caudal band is variable. The band is generally dull white or gray on captive fish. This appears to be true of all of the species of *Acanthurus* which have a white or light gray caudal base.

The blue and yellow colors of specimens of *A. mata* collected from bays were noticeably duller than these colors on specimens from clear outer reef areas.

There is no type specimen of *Acanthurus mata*. The name and description originated with the prelinnaean author Russell whose work I have not seen. Cuvier (1829: 224) cited Russell when he listed *Chaetodon meta* among the surgeon fishes in his *Règne Animal*. This appears to be an error for *mata*, for all subsequent authors, some of whom have referred to Russell, have spelled the name *mata*. Cuvier and Valenciennes (1835: 202) gave a brief description based on Russell. Their reference to the similarity to *Acanthurus dussumieri*, the dark body color with blue on the head and elsewhere, and a size up to 18 inches constitutes the principal basis for my calling the species, as here defined, *Acanthurus mata*.

Schultz and Woods (1953: 640) correctly assigned the name *Acanthurus mata* to two large specimens (280 and 310 mm.) from the northern Marshall Islands. These authors proposed that the name *mata* be restricted to Plate 48, Figure 1 of Day (1876); however, this figure appears to be *Acanthurus nigrofuscus* (Forskål).

I have been unable to identify or can only tentatively identify many of the records in the literature which may be *A. mata* because of insufficient descriptive information. To my knowledge, the species has never been figured.

Most of the unquestioned names in my synonymy for the species are based on the examination of specimens. *Acanthurus blochi* of Streets (1877: 68), for example, are small specimens of *A. mata*. Fowler and Bean (1929: 246) were in error in considering these as *Hepatus glaucopareius*.

Although the color seems a little different, the species from Africa identified as *Acanthurus lineolatus* by Smith (1949: 240, pl. 33, fig. 609) is probably *A. mata*. A 71 mm. specimen kindly loaned by Smith proved to be *Acanthurus bleekeri*, however.

### *Acanthurus monroviae* Steindachner

Figs. 2z, 21

*Acanthurus phlebotomus*. Troschel (*non* Cuvier and Valenciennes) (1866: 227) (Cape Verde Islands).

*Acanthurus Monroviae* Steindachner (1876: 160) (Monrovia, Liberia).

*Acanthurus chirurgus*. Peters (1876: 246) (Victoria, Cameroon, West Africa).

*Acanthurus monroviae* Steindachner (1895: 18) (mouth of Messurado River and Cape Mount, Liberia); Metzelaar (1919: 256) (Senegal Coast, West Africa).

*Teuthis munroviae* Gill (1896: 188) (error for *monroviae*).

Dorsal rays IX, 25 to 27; anal rays III, 24 to 26; pectoral rays 17; anterior gill rakers 16 or 17; posterior gill rakers 16; an 88 mm. specimen has 12 upper and 14 lower teeth; a 192 mm. specimen has 18 upper and 18 lower teeth. These counts and the measurements given below were obtained from two specimens from Liberia which are in the United States National Museum.

Depth of body 2.0 (in 192 mm. specimen) to 2.2 (in 88 mm. specimen) in standard length; caudal concavity 7.6 (in 192 mm. specimen) to 10.4 (in 88 mm. specimen) in standard length; diameter of eye 3.5 (in 88 mm. specimen) to 4.0 (in 192 mm. specimen) in head length; length of snout 4.9 to 5.2 in standard length; length of longest dorsal

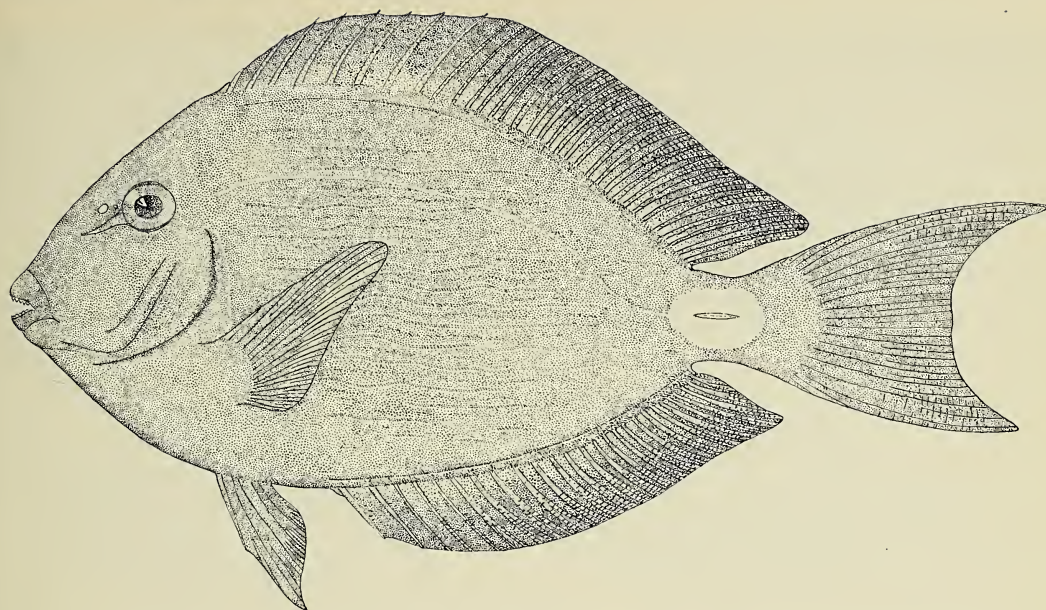


FIG. 21. *Acanthurus monroviae*. 192 mm. specimen, Liberia. Drawing by L. B. Isham, United States National Museum.

ray 4.9 to 5.1 in standard length; length of pectoral fin 3.4 (in 88 mm. specimen) to 3.6 (in 192 mm. specimen) in standard length; length of caudal spine 4.5 to 5.7 in head length.

Color (in alcohol) of 88 mm. specimen brown with a white area (in height slightly less than diameter of eye) around caudal spine; about 15 narrow, dark, undulating lines on side of body; opercular membrane very dark brown; area around edge of upper limb of preopercle very dark brown; median fins very dark brown except extreme margin of central part of caudal fin which is pale; pectoral fin rays dusky except for outer part of lower 11 rays which are pale; pectoral membranes pale; pelvic fins very dark brown. The 192 mm. specimen differs in color in having more numerous and less conspicuous lines on the body, a relatively larger pale area around the caudal spine (in height almost one-third the head length), black median fins except base of dorsal and anal which are brown, and the margin of the preopercle only slightly darker than the rest of the head.

The pale spot around the caudal spine was described as yellow in life. Peters (1876) mentioned a blue border around this yellow area. Both Peters and Steindachner described the lines on the body as blue.

Fowler (1936: 912) erroneously synonymized this species with *Hepatus hepatus* (= *Acanthurus chirurgus*).

*Acanthurus monroviae* is known only from West Africa.

#### ***Acanthurus coeruleus* Bloch and Schneider** Figs. 2aa, 22

*Acanthurus Coeruleus* Bloch and Schneider (1801: xxxviii, 214) (Carolina and Havana).

*Acanthurus Broussonnetii* Desmarest (1823: 26, pl. 3, fig. 1) (Cuba).

*Acanthurus caeruleus* Cuvier and Valenciennes (1835: 175) (Martinique, Puerto Rico, and Santo Domingo); Castelnau (1855: 25) (Bahia, Brazil); Günther (1861: 336) (West Indies, Caribbean Sea, and Bahia); Poey (1868: 355) (Cuba); Beebe and Tee-Van (1928: 184) (Port-au-Prince Bay, Haiti);



Breder (1929: 221); Beebe and Tee-Van (1933: 179) (Bermuda); Longley and Hildebrand (1941: 155) (Tortugas, Florida).  
*Acanthurus coeruleus* Storer (1846: 112); Lütken (1880: 609, pl. 5, fig. 3) (Antilles); Jordan and Gilbert (1882: 617); Meek and Hildebrand (1928: 782) (Atlantic coast of Panama).  
*Acanthurus violaceus* Castelnau (1855: 25).  
*Acanthurus brevis* Poey (1860: 207) (Cuba); Poey (1868: 355).  
*Acronurus caeruleatus* Poey (1875: 69, pl. 3, figs. 15 to 17 of developing scales) (Cuba).  
*Acanthurus nigricans*. Goode (1876: 41) (Bermuda).  
*Teuthis coeruleus* Meek and Hoffman (1884: 228); Evermann and Marsh (1902: 253, pl. 38) (Puerto Rico).  
*Teuthis helioides* Barbour (1905: 127, pl. 3) (Bermuda).  
*Hepatus caeruleus* Fowler (1916: 405) (Colon, Panama).  
*Hepatus pawnee* Breder (1927: 73, fig. 32) (Glover Reef, British Honduras).  
*Teuthis caeruleus* Nichols and Breder (1927: 134) (New York).  
*Acanthurus helioides* Beebe and Tee-Van (1933: 179) (error for *helioides*) (Bermuda).  
*Teuthis (Rhomboteuthis) coeruleus* Fowler (1944a: 109, pl. 13, upper left fig.) (Courtown Keys, Caribbean Sea).

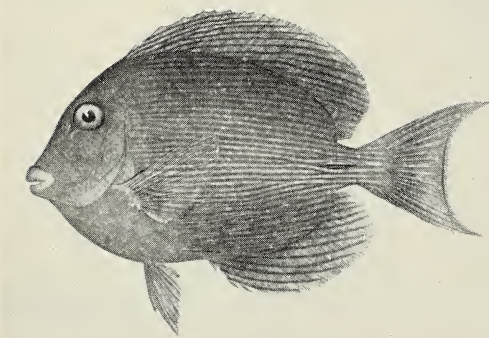


FIG. 22. *Acanthurus coeruleus* (after Jordan and Marsh, 1902).

*Acanthurus hepatus*. Carvalho (1952: 115, fig.) (Trinidad).

Dorsal rays IX, 26 to 28; anal rays III, 24 to 26; pectoral rays 16 or 17; anterior gill rakers 13 or 14; posterior gill rakers 13 (raker counts from specimens from Bermuda to Brazil); a 38 mm. specimen has 8 upper and 10 lower teeth; an 82 mm. specimen has 10 upper and 12 lower teeth; 90 and 115 mm. specimens have 12 upper and 14 lower teeth; a 235 mm. specimen has 14 upper and 16 lower teeth.

TABLE 22  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus coeruleus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS			ANAL SOFT RAYS		
	26	27	28	24	25	26
Bermuda.....		2	1		2	1
Florida.....	1		2	1	2	
West Indies.....	3	11	2	2	11	3
Brazil.....		1	1		1	1

Depth of body 1.7 in standard length; caudal concavity varies from 11.7 in standard length in an 82 mm. specimen to 7.7 in a 115 mm. specimen, to 5.3 in a 178 mm. specimen, and 5.1 in a 235 mm. specimen; caudal spine 6.5 in head length of an 82 mm. specimen, 3.7 in 235 mm. specimen; length of pectoral fin 2.8 to 2.95 in standard length; diameter of eye 3 in head length of an 82 mm. specimen and 4.5 in head length of a 235 mm. specimen.

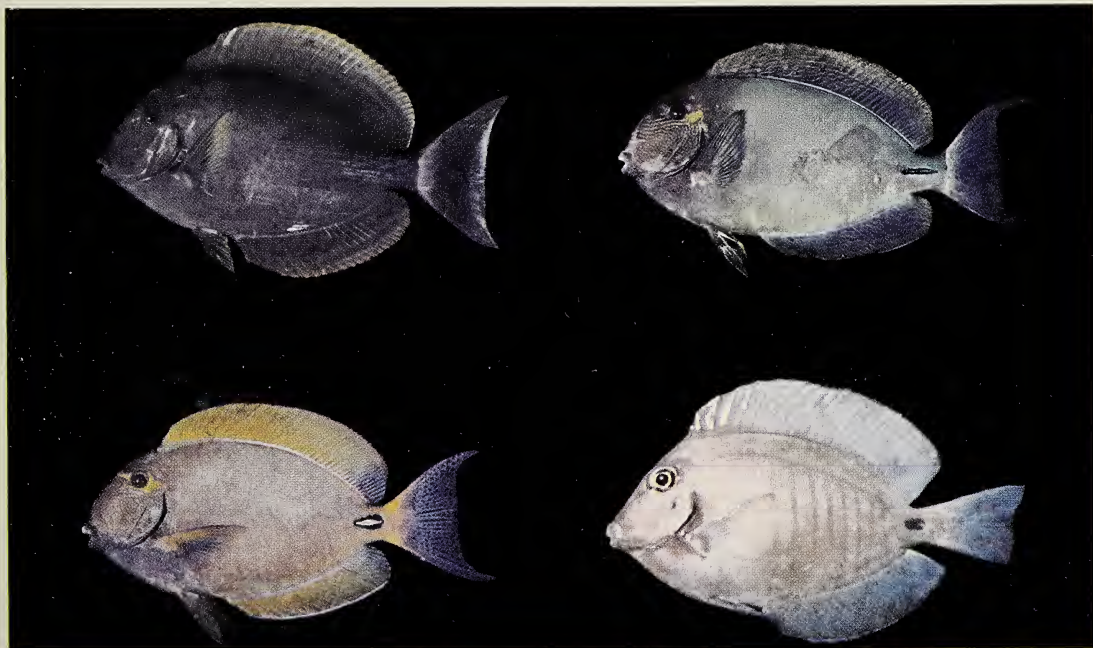
Color (in alcohol) grayish brown with alternating dark and light, slightly irregular, longitudinal lines on body (the light lines are about three times as broad as the dark); lines on dorsal part of body angle upward to dorsal fin; caudal fin grayish brown with a very narrow pale posterior margin and a dark submarginal band about four times as broad as the pale margin; dorsal fin with about seven dark longitudinal bands in the spinous portion and nine in the soft portion; anal fin with



*Acanthurus fowleri.*  
*Acanthurus maculiceps.*

*Acanthurus bariene.*  
*Acanthurus gabbm.*

From paintings of the Philippine "Albatross" Expedition, 1909, in the Division of Fishes, United States National Museum. Reproduced by courtesy of Leonard P. Schultz.



*A. xanthopterus*, 174 mm. specimen, Hawaiian Islands.  
*A. dussumieri*, 255 mm. specimen, Hawaiian Islands.

*A. mata*, 269 mm. specimen, Hawaiian Islands.  
*A. chirurgus*, Florida (pale phase).

(Note scratches and reflections on figures.)





about five longitudinal dark bands; margins of dorsal and anal fins dark brown; pectoral fins pale; pelvic fins dark brown; no dark area around caudal spine; sheath of caudal spine pale.

A 125 mm. specimen speared by the writer at Nassau, Bahamas, provided the following color note: body purplish gray with 26 irregular dark gray longitudinal lines; dorsal and anal fins bright blue with orange-brown longitudinal bands; caudal fin blue, shading to yellowish gray in center; pectoral fins clear yellow; pelvic fins blue; sheath of caudal spine white. Some specimens observed underwater had three vertical pale bars on the body.

Townsend (1929: 19, pl. 21) described and figured three color phases of this species from aquarium observations, a blue, a blue with three or four pale vertical bars, and a creamy white with blue margins on the fins. The latter phase was seldom seen until evening when the fish settled toward a white sand bottom. Longley (1941: 155) observed that the species was very light over a pale sandy bottom.

Longley also observed that the young are clear yellow, and he correctly referred *Teuthis helioides* Barbour to the synonymy of *Acanthurus coeruleus*. He stated that specimens up to 100 or 125 mm. in length may be yellow. His length measure is probably total length. The longest yellow specimen which I have seen is the type of *Teuthis helioides* in the Museum of Comparative Zoology (No. 29053). It is 77 mm. in standard length. The size at which the blue-gray color replaces the yellow is variable. I speared a 31 mm. specimen at Nassau which was blue except for the middle of the caudal fin which was yellow.

The largest specimen of *A. coeruleus* seen by me is a 235 mm. one from Bermuda. Another from Bimini is 234 mm. in standard length.

Lütken (1880: pl. 5, figs. 3, 4, and 5) figured the postacronurus, acronurus, and a 5.7 mm. postlarval specimen of *A. coeruleus*. The postacronurus has three vertical pale bands on the body.

*Hepatus pawnee* Breder (1927: 73, fig. 32) is apparently the acronurus of *A. coeruleus*, judging from the deep body and the fin ray counts D IX, 27 and A III, 25. It was taken at a night light at Glover Reef, British Honduras.

Fowler (1944a: 109) proposed the subgenus *Rhomboteuthis* for *A. coeruleus*. As previously discussed (Randall, 1955b), this does not seem justified.

Longley (1941: 155) pointed out that *A. coeruleus* is seen more often well above the bottom than the other two surgeon fishes commonly seen in Florida waters, *A. chirurgus* and *A. bahianus*. He stated that the food of *A. coeruleus* is wholly algal like that of *A. chirurgus* and *A. bahianus* but contains less sand and bottom debris than that of the latter two species. This is consistent with the structure of the stomach of these three species. *A. coeruleus* has a thin-walled stomach, whereas the other two species have heavy-walled, gizzard-like stomachs. Breder and Clark (1947: 295, fig. 1) described the morphology of the digestive tract of *A. coeruleus*.

### *Acanthurus chirurgus* (Bloch)

Figs. 1b, 2bb, Pl. 3

*Chaetodon chirurgus* Bloch (1787: 204, pl. 208) (Martinique).

*Acanthurus Chirurgus* Bloch and Schneider (1801: xxxviii, 214) (Caribbean Sea).

*Acanthurus Hepatus*. Bloch and Schneider (in part) (1801: 211) (America and Bahama Islands).

*Acanthurus chirurgus* Lacépède (1802: 546); Cuvier and Valenciennes (1835: 168) (Martinique, Puerto Rico, Cuba, and Brazil); Storer (1846: 112); Günther (in part) (1861: 329) (Caribbean Sea, West Indies, Venezuela, and Brazil); Günther (1869: 238) (St. Helena); Goode (1876: 42) (Bermuda); Jordan and Gilbert (1882: 617); Metzelaar (1919: 256) (both sides of Atlantic).

*Acanthurus phlebotomus* Cuvier and Valenciennes (1835: 176, pl. 287) (Martinique,



Brazil, Havana, and New York); Storer (1846: 111); Poey (1868: 355) (Cuba).  
*Acanthurus chirurgicus* Castelnau (1855: 24) (Bahia, Brazil).  
*Acanthurus nigricans*. Jordan and Gilbert (1882: 941).  
*Teuthis hepatus*. Meek and Hoffman (1884: 229); Jordan and Evermann (1898: 1691); Evermann and Marsh (1902: 254) (Puerto Rico); Nichols and Breder (1927: 134) (New York); Gudger (1929: 196) (Tortugas, Florida); Fowler (1944a: 110, pl. 13, right hand figs.) (Courtown Keys, Caribbean Sea).  
*Hepatus hepatus*. Fowler (1916: 403) (Colon, Panama); Fowler (1936: 912, fig. 385) (West Africa).  
*Acanthurus hepatus*. Meek and Hildebrand (1928: 784) (Atlantic coast of Panama); Beebe and Tee-Van (1928: 185) (Port-au-Prince Bay, Haiti); Breder (1929: 221); Beebe and Tee-Van (1933: 181, col. pl. 4, incorrectly labelled *Acanthurus caeruleus*) (Bermuda); Longley and Hildebrand (1941: 156) (Tortugas, Florida).  
Dorsal rays IX, 24 or 25; anal rays III, 22 or 23; pectoral rays 16 or 17; anterior gill rakers 16 to 19; posterior gill rakers 15 to 18 (raker counts from West Indian specimens); 32 mm. and 54 mm. specimens have 10 upper and 12 lower teeth; a 140 mm. specimen has 16 upper and 18 lower teeth; a 184 mm. specimen has 18 upper and 20 lower teeth.

TABLE 23  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus chirurgus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS		ANAL SOFT RAYS	
	24	25	22	23
Massachusetts.....	1	1	1	1
Bermuda.....		1	1	
Florida.....		2		2
West Indies.....	9	22	10	21
Brazil.....	1		1	

Depth of body about 2 in standard length; caudal fin emarginate (nearly truncate in young), caudal concavity about 14 to 18 in standard length; length of caudal spine 5 in head length of a 54 mm. specimen, 3.5 in a 165 mm. specimen; length of pectoral fin 3 in standard length; diameter of eye 2.9 in standard length of a 54 mm. specimen, 3.8 in a 184 mm. specimen.  
Color (in alcohol) brown, usually with 10 to 12 long vertical dark brown bars visible on side of body; caudal spine enclosed in a very dark brown area, the height of which is about three times the maximum width of the spine; no definite white posterior margin to caudal fin (extreme tips of caudal rays pale, resulting in a very narrow, irregular, white margin); dorsal fin with nine diagonal dark bands in spinous portion (two to seven on each interspinous membrane) and nine or ten in soft portion (these mostly longitudinal); anal fin with four similar bands (the bands in the fins often fade completely in preservative); margins of dorsal and anal fins narrowly dark brown; outer one-third of pectoral fin pale in adult specimens; membranes of pelvic fins very dark brown; opercular membrane black.  
The color photograph of *A. chirurgus* from which Plate 3 was reproduced was taken of a specimen collected by the author in a sandy region at Soldier Key, Florida. It is in a pale color phase. Over a dark substrate the species is usually brown as shown in the two lower figures of plate 22 in Townsend (1929). Longley (1941: 156) described the color phases of this species in detail.  
The largest specimen seen by me measured 228 mm. It was taken at Panama.  
*A. chirurgus* is probably the most wide-ranging species of *Acanthurus* in the Atlantic, apparently occurring on the coast of West Africa as well as the entire tropical and sub-tropical regions of the West Atlantic. Its extension into cooler waters of the northeast United States (such as Massachusetts) is probably a result of transport of the larvae by

the Gulf Stream from more southern regions where resident populations are established. The specimens which I have seen from such northern localities have all been juveniles or subadults. The same applies to specimens of *A. coeruleus* and *A. bahianus*. Breder (1929: 222) stated that *A. chirurgus* is the most common species of the family on the Atlantic coast of the United States.

Townsend (1929: 19) reported that this fish lives well in captivity. Although largely herbivorous, specimens were kept as long as five years in the New York Aquarium on a fish and clam diet varied occasionally with seaweed.

Longley (1941: 156) pointed out, and I have verified his observation, that *Acanthurus chirurgus* often swims in small schools with *A. bahianus*.

After first doubting Longley's placing of *Hepatus pawnee* in the synonymy of *Acanthurus hepatus* (= *Acanthurus chirurgus*), Breder (1949: 296) decided he was correct. I believe, however, that *H. pawnee* as figured by Breder (1927: fig. 32) is the acronurus of *Acanthurus coeruleus*. If the fin ray counts D IX, 27; A III, 25 are correct, no other conclusion could be drawn (see Tables 22 to 24).

Many recent authors have applied the name *Acanthurus hepatus* to the species *Acanthurus chirurgus*. Three different species of surgeon fishes of five prelinnaean authors were cited by Linnaeus (1766: 507) under the name *hepatus*. Cuvier and Valenciennes were the first to restrict the name. They used it for the East Indian species of Seba (1734: 104, pl. 33, fig. 3) which is now recognized as the single species in the genus *Paracanthurus*.

### *Acanthurus bahianus* Castelnau

Figs. 1c, 2c, 23

*Acanthurus bahianus* Castelnau (1855: 24, pl. 11, fig. 1) (Bahia, Brazil); Meek and Hildebrand (1928: 783) (Atlantic coast of Panama); Beebe and Tee-Van (1928: 184) (Port-au-Prince Bay, Haiti); Breder (1929:

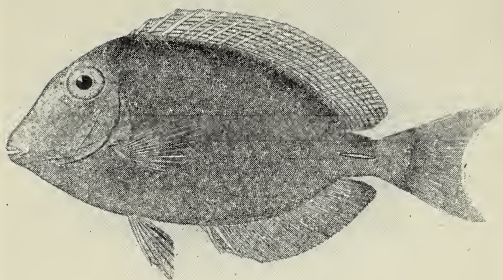


FIG. 23. *Acanthurus bahianus* (after Jordan and Evermann, 1900, retouched).

222); Beebe and Tee-Van (1933: 180) (Bermuda); Longley and Hildebrand (1941: 156) (Tortugas, Florida).  
*Acanthurus tractus* Poey (1860: 208) (Cuba); Poey (1868: 356); Jordan and Gilbert (1882: 941).  
*Acanthurus chirurgus*. Günther (in part) (1861: 329) (Caribbean Sea and Brazil).  
*Acronurus nigriculus* Poey (1875: 69, pl. 3, figs. 18 and 19 of scales and caudal fin) (Cuba).  
*Teuthis tractus* Meek and Hoffman (1884: 229).  
*Teuthis bahianus* Jordan and Evermann (1898: 1693) (Key West, Florida and Bahia, Brazil); Jordan and Evermann (1900: pl. 256, no. 629); Evermann and Marsh (1902: 254, fig. 70) (Puerto Rico); Nichols and Breder (1927: 135) (Woods Hole); Gudger (1929: 197) (Tortugas, Florida); Fowler (1944a: 110, pl. 13, lower left fig.) (Courtown Keys, Caribbean Sea).  
*Hepatus bahianus* Fowler (1916: 405) (Colon, Panama).  
*Teuthis coeruleus*. Gudger (1929: 196) (Tortugas, Florida).

Dorsal rays IX, 23 to 26; anal rays III, 21 to 23; pectoral rays 15 to 17 (usually 16); anterior gill rakers 20 to 22; posterior gill rakers 17 to 19 (raker counts from West Indian specimens); a 55 mm. specimen has 12 upper and 12 lower teeth; an 85 mm. spec-



imen has 12 upper and 14 lower teeth; a 100 mm. specimen has 14 upper and 16 lower teeth; a 170 mm. specimen has 14 upper and 16 lower teeth.

Depth of body about 2 in standard length; caudal concavity varies from 13.5 in a 68 mm. specimen to 8.3 in a 124 mm. specimen to 4.6 in a 170 mm. specimen; length of caudal spine 3.5 in head length of a 105 mm. specimen, 2.8 in a 155 mm. specimen; length of pectoral fin 3 in standard length of a 105 mm. specimen, 3.5 in standard length of a 155 mm. specimen; diameter of eye 3 in head length of a 105 mm. specimen, 3.5 in 155 mm. specimen.

TABLE 24  
VARIATION IN FIN RAY COUNTS OF SPECIMENS OF  
*Acanthurus babianus* FROM DIFFERENT LOCALITIES

LOCALITY	DORSAL SOFT RAYS				ANAL SOFT RAYS		
	23	24	25	26	21	22	23
Massachusetts . . .	1					1	
Bermuda . . . . .			2				2
Florida . . . . .		2	1		1	2	
West Indies . . . .	2	19	8	1	2	21	7
Brazil . . . . .		3	1			3	1

Color (in alcohol) brown, with or without narrow, faint, longitudinal lines on body; caudal fin with a definite white posterior margin which is broader in median part of fin (in maximum width about one-third the diameter of the pupil in adults, proportionally wider in young); base of caudal fin usually paler than rest of body; 9 to 11 narrow longitudinal dark lines usually visible in dorsal fin; anal fin with about four similar bands, but these usually fade in preservative; margins of dorsal and anal fins narrowly dark brown; pectoral fins light brown; membranes of pelvic fins dark brown; margin of caudal spine socket narrowly black; sheath of caudal spine dark brown; opercular membrane black.

Color in life of a 121 mm. specimen collected by the author at Bache Shoal, Florida:

body light yellowish brown with faint pale greenish gray longitudinal lines (ventrally the body is dull brassy yellow and the lines are light grayish blue); throat pale grayish blue; caudal fin olive-yellow, the posterior margin bluish white; margin of dorsal and anal fins bright blue; dorsal fin with alternating lengthwise bands of dull orange and light bluish green; anal fin with alternating grayish blue and dark gray bands; pectoral rays dusky orange, membranes hyaline; pelvic rays pale blue, membranes black; a narrow violet area surrounding caudal spine; upper one-fourth of opercular membrane purple, lower three-fourths black; a purplish gray area adjacent to posterior edge of eye, this region crossed by six to seven narrow yellow lines which radiate from eye; a few small yellow spots below eye; a short blue line anterior to eye.

Longley (1941: 157) stated that this species is golden brown on the open reef and matches very well the dominant color of the algae on which it may be seen cropping all day long. Like *A. chirurgus*, it readily displays a very pale color phase.

The largest specimen seen by me measures 170 mm. in standard length. It was collected at Cuba.

I examined the type specimen of *Acanthurus tractus* Poey at the Museum of Comparative Zoology. Without doubt it is *A. babianus*.

*A. babianus* appears to be confined to the western Atlantic. It is known from Brazil to Massachusetts.

DOUBTFUL SPECIES

*Acanthurus doreensis* Cuvier  
and Valenciennes

*Acanthurus doreensis* Cuvier and Valenciennes (1835: 220) (Dorey Harbor, New Guinea); Bleeker (1850a: 5); Günther (1861: 332); Macleay (1883: 354).

*Rhombotides doreensis* Bleeker (1878: 51).

*Hepatus doreensis* Fowler (1928: 268); Jordan and Seale (1906: 351).

To my knowledge the species is known only from the type (No. A 7099) in the Paris Museum. It was described by Valenciennes as brown with the posterior part of the pectoral yellowish and the terminal border of the caudal fin with a white margin. The length was given as 8 inches. The fin ray counts D IX, 28 and A III, 20 are most distinctive, and on the basis of these Bleeker, Günther, Macleay, and Fowler all regarded the species as valid. Jordan and Seale, however, suggested that it might be the young of *Hepatus nigricans* (= *Acanthurus gabhm*) or *H. elongatus* (= *A. nigrofuscus*), and that the anal rays of the specimen were miscounted. These authors are probably in error in considering it a juvenile, for an eight-inch specimen of any known species of *Acanthurus* would be an adult or near-adult.

L. Bertin of the Paris Museum has kindly supplied the following information on the type. It is 166 mm. in standard length, has a caudal concavity of 20 mm., and 16 upper and 18 lower teeth. No black bar can be perceived on the shoulder region of the specimen. There are 28 dorsal soft rays and 20 anal soft rays. "Aucun doute à cet égard."

Of the known species of *Acanthurus*, *A. doreensis* is closest to *A. grammoptilus* Richardson. The number of teeth in the jaws, shape of the caudal fin, yellowish outer part of the pectoral fin, white posterior margin of the caudal fin, and lack of a definite mark on the shoulder region are characteristic of the latter species. The usual soft fin ray counts of D 26 and A 24 of *A. grammoptilus* do not seem to offer any possibility, however, even in the extreme range of normal variability, of ever being D 28 and A 20. In fact, the latter combination of counts can be found in no species of *Acanthurus*. It would seem, therefore, that *A. doreensis* is either an abnormal specimen of *A. grammoptilus* or is a good species. Decision on the matter should await the collection of further specimens.

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## NOTES

### Tagged Bigeye Tuna Recovered

A bigeye tuna (*Parathunnus sibi*) tagged by the Pacific Oceanic Fishery Investigations in the North Pacific was recently recaptured by the Japanese during their winter longline operations in waters north of the Hawaiian Islands, marking the first known bigeye tag recovery in the Pacific.

The fish was tagged on January 31, 1955, by the U. S. Fish and Wildlife Service research vessel *John R. Manning* (cruise 23), at 30° 59'N, 171° 14'W, which is about 360 miles northeast of Midway Island, during an albacore survey cruise to the North Pacific. The tuna, captured by longline, measured 122.3 cm. in fork length at the time of release.

The recovery was made by a Japanese longline vessel, the *No. 5 Nikko Maru*, of the Nikko Fishing Company of Fukushima Prefecture, on November 24, 1955, at 32° 41'N, 155° 57'W, approximately 700 miles due north of Oahu, T. H. The straight-line distance between the points of release and recovery is 800 miles.

The length of the fish at recapture was 126.8 cm., indicating a net gain in length of 4.5 cm. during the interval of 10 months. In terms of estimated weight this represents a gain of approximately 10 pounds.

This recovery was the first from a total of 82 bigeye tuna tagged and released in North Pacific waters by POFI between January, 1954, and September, 1955. The tag, in excellent condition, together with pertinent information regarding its recovery, was returned to the Pacific Oceanic Fishery Investigations laboratory through the cooperation of Mr. Shoji Ueyanagi of the Nankai Regional Fisheries Research Laboratory of Kochi, Japan. The tag used was a type "G" vinyl plastic tube tag recently developed by the California Department of Fish and Game (Wilson, R. C., 1953, Calif. Fish and Game 39(4):429-442).—*Tamio Otsu and Richard N. Uchida, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu.*

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## News Notes

Sheet 10 (the third received) of the geological map of New Caledonia and the accompanying explanatory notes have been received. For details of the map series see *Pacific Science* 8(3):369.

The address of the Office de la Recherche Scientifique et Technique Outre-Mer has been changed to 47, boulevard des Invalides, Paris-7<sup>e</sup>.

BODEN, BRIAN P., MARTIN W. JOHNSON, and EDWARD BRINTON. *Euphausiacea (Crustacea) of the North Pacific*. Scripps Institution of Oceanography, of the University\* of California, Bulletin. Vol. 6, No. 8, pp. 287-400, 55 figs. University of California Press, Berkeley and Los Angeles. \$1.50.

Scientific expeditions, planning field work in the Melanesian, Indonesian, Philippine, Micronesian or Polynesian areas, will be interested to know that the "Gloria Maris," a 107-foot, steel-hulled, two-masted auxiliary schooner, is now available for charter in that area. The "Gloria Maris," owned by Alfred J. Ostheimer III, of Philadelphia, and chartered on a long-term basis to the Natural Science Foundation in Philadelphia, can be sub-chartered on a bareboat basis provided that Captain Ernest Chamberlain (her permanent skipper) and his experienced crew are engaged separately. Bargain charter rates are offered to scientific groups, since the Foundation's primary interest is to offset expenses rather than to make money.

The "Gloria Maris" recently completed an expedition in the Palau Islands for the purpose of collecting marine mollusks under the auspices of The Academy of Natural Sciences of Philadelphia and the Natural Science Foundation. She is temporarily based at Koror in the Palau Islands, subject to further marine mollusk collecting trips under the same auspices or such charters as can be arranged. The "Gloria Maris" can accommodate a scientific party of eight to ten individuals in comfort and has space and facilities for scientific work.

The Natural Science Foundation is also interested in locating individual scientists who might arrange to accompany future marine mollusk collecting expeditions to do field work in their own specialties in South and West Pacific areas.

Obviously, there are opportunities for collecting and field studies which are entirely compatible with mollusk collecting work and the Foundation would consider providing board and lodging on the "Gloria Maris" for those able to provide their own transportation to and from the area.

Of outstanding importance to all workers concerned with decapod crustaceans is the recently received paper by Dr. L. B. Holthius, "The recent genera of the caridean and stenopodidean shrimps (class Crustacea, order Decapoda, supersection Natantia) with keys for their determination." It is published as *Zoologische Verhandelingen* No. 26 of the Rijksmuseum van Natuurlijke Historie te Leiden, by E. J. Brill, Leiden.





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*Introduction and summary.* It is desirable to state the purpose and scope of the paper in an introductory paragraph and to give a summary of results at the end of the paper.

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BATZO, RODERICK L., and J. K. RIPKIN. 1849. *A treatise on Pacific gastropods*. vii + 326 pp., 8 figs., 1 map. Rice and Shipley, Boston.

CRAWFORD, DAVID L. 1920*a*. New or interesting Psyllidae of the Pacific Coast (Homop.). *Ent. News* 31 (1): 12-14.

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NO. 3

# PACIFIC SCIENCE

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(Continued on inside back cover)

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## Notes on the Blennioid Fishes of Hawaii with Descriptions of Two New Species

DONALD W. STRASBURG<sup>1</sup>

ALTHOUGH NEARLY EVERY REPORT on the Hawaiian inshore fishes alludes to the blennies, the Hawaiian members of this group have never been reviewed in their entirety. Jordan and Evermann (1905) discuss and figure most of the common forms, while Jordan and Seale (1906) and Fowler and co-authors (1901, 1922, 1925, 1928, 1949) present supplemental data. Unfortunately the taxonomy employed in the above reports is sometimes inaccurate because of the close resemblance between Hawaiian blennies and those of other areas, and in a few instances it errs because of a species being based on a larval or sexual form. There are overall problems of a lack of adequate keys and of generic names not being up to date.

This paper was prepared with a three-fold purpose. It attempts to clarify certain nomenclatorial problems, it provides a key and a description for the identification of each Hawaiian species, and it reports two hitherto undescribed forms as new, along with a new record of a previously known species. The geographical scope of this study includes the high or windward Hawaiian Islands, the leeward islets and shoals extending from Niihau northwest to Midway Island, Midway Island itself, and Johnston Island. Specimens have been taken from numerous islands in this

assemblage, with the major collecting emphasis being on Oahu, in the windward Hawaiian chain. Where synonymies are given they refer only to Hawaiian records unless otherwise noted.

### ACKNOWLEDGEMENTS

I am greatly indebted for assistance received from numerous individuals and institutions. Dr. William A. Gosline and other staff members of the University of Hawaii aided me in collecting many of the specimens examined. The Museum of Comparative Zoology at Harvard College sent certain early collections of Hawaiian blennies; Dr. J. L. B. Smith loaned a South African specimen of *Entomacrodus*; and Dr. Itiro Tomiyama supplied specimens of several Japanese blennies. Drs. N. B. Marshall and Gilbert P. Whitley, of the British and Australian Museums respectively, examined type material unavailable to me. I am grateful for permission to examine specimens and use various facilities at the United States National Museum, the American Museum of Natural History, the Bernice P. Bishop Museum, the University of Hawaii, the Pacific Oceanic Fishery Investigations (U. S. Fish and Wildlife Service, Honolulu), and the Territorial Division of Fish and Game (Honolulu). In this report these institutions are referred to as follows: USNM, AMNH, BPBM, UH, POFI, and DFG. The

<sup>1</sup> United States Fish and Wildlife Service, Honolulu. Work done at Duke University, Durham, N. C. Manuscript received May 23, 1955.



Museum of Comparative Zoology at Harvard College is abbreviated as MCZ. Mr. James K. Park of Honolulu prepared Figure 2.

#### METHODS

The Hawaiian blennioid fishes include representatives of the families Blenniidae and Tripterygiidae. As pointed out by Clark Hubbs (1952: 50), these families are readily distinguishable by the presence of scales in the Tripterygiidae and by their universal absence in the Blenniidae (except in *Neoclinus*, which does not occur in Hawaii). In addition to the presence of scales, the three dorsal fins and bright red coloration render the single Hawaiian tripterygiid a readily identifiable form.

Norman's analysis of the genera (1943), supplemented by Schultz's definition of *Runula* (1950) and Strasburg and Schultz's of *Cirripectus* and *Exallias* (1953), constitutes the basis for generic subdivision of the Hawaiian Blenniidae. The need for dividing certain heterogeneous genera such as *Istiblennius* has been implied by Norman (*op. cit.*), but it is felt that such separation should be made in monographic treatments and not in a faunal report. The Hawaiian blennies can be subdivided into the subfamilies Blenniinae and Salariae as shown by Norman (*op. cit.*), but it appears that his Ophioblenniinae may represent only larval forms.

In the following key considerable use has been made of meristic characters, and the methods used in counting certain structures need explanation. Each fin ray with a separate and distinct base was counted as one, and those rays split to a single base were also counted as one ray. Spines and soft rays are sometimes difficult to distinguish in the Hawaiian blennies, but can often be differentiated when the fin is held before a strong light, or by removing the membrane from one side of the fin. In general, the spines are soft and flexible but rather more slender than articulated rays. In certain genera the dorsal

fin membrane is notched between the spinous and soft-rayed portions, and the minute last dorsal spine occurs at the base of this notch. In those genera having the dorsal fin entire the last dorsal spine is about the same size as the penultimate one.

The anal fin of Hawaiian blennies is composed of two short, weak spines (only one spine in the tripterygiids) followed by a series of longer soft rays. Aside from their length it is practically impossible to distinguish anal spines from rays without dissection and staining, and the problem is further complicated in female blenniids where the first spine becomes embedded in genital tissue with growth. In adult male *Cirripectus* and *Exallias* each anal spine is enclosed in a mass of spongy tissue, the presence of which facilitates sex determination.

The methods employed by Strasburg and Schultz (1953: 129) have been used for counting head cirri. A nuchal cirrus was counted as one if it had a single base, cirri with distal or basal branches thus being enumerated as one. The degree and type of branching of supraorbital cirri was found to be useful in distinguishing species of *Cirripectus*, and the morphology of these structures is discussed in the key and species diagnoses.

An important characteristic of some blenniids is their possession of canine teeth in addition to numerous small incisors. Canines range in size from short stubs in *Entomacrodus* to large fangs in *Runula*, but are lacking in *Istiblennius zebra* and *Exallias*. When present, canines occur posteriorly in the jaws and mesial to the incisors.

Many Hawaiian blennies have relatively large larvae which are considerably different from the adults. In a few cases such larvae have been the basis for the erection of genera and species, and only recently (Chapman, in de Beaufort and Chapman, 1951: 249-254) have they been recognized as larval forms. Larvae are readily distinguished from juveniles by their glassy transparency when alive and their nearly uniform straw or white coloration

5a. Body dark brown, marked with small



- white or yellowish dots arranged in three to five lengthwise rows, sometimes also marked with tiny black dots; supraorbital cirrus slender, normally unbranched, if branched, filaments (not more than 5) arise from a central axis; dorsal rays usually XII, 15; anal rays usually II, 16; nuchal cirri totaling 25 to 32, usually 26 to 30; membranous attachment of last dorsal ray to caudal peduncle ending directly above flexure marking caudal base; line separating dusky and pale portions of dorsal fin running from base of first spine to tip of about sixth spine. . . . .
- ... *Cirripectus lineopunctatus*, n. sp.
- 5b. Body uniform tan to brownish black, unmarked; supraorbital cirrus multifid, 4-11 (usually 5-8) branches arising from a broad base; dorsal rays XII, 14; anal rays II, 15; nuchal cirri totaling 31 to 43, usually 32 to 40; membranous attachment of last dorsal ray to caudal peduncle ending about one pupil diameter, or more, posterior to flexure marking caudal fin base; line separating dusky and pale portions of dorsal fin running from base of first spine to tips of anterior soft rays. . . . .
- ... *Cirripectus variolosus*
- 6a. Teeth, excluding canines, loosely set in gums and freely movable (only in upper jaw of *Ecsenius*); gill opening large, elongate, extending beyond base of pectoral fin both dorsally and ventrally. . . . . 7
- 6b. Teeth in both jaws firmly attached, practically immovable; gill opening restricted to a narrow slit commencing above pectoral base and running ventrally to level of middle pectoral rays. 10
- 7a. A cirrus present over each eye; dorsal fin with deep notch between spinous and soft-rayed portions; more than 100 incisiform teeth in lower jaw, freely movable; dorsal spines XIII (very rarely XII); a single multifid cirrus on each anterior nostril. . . . . 8
- 7b. No supraorbital cirrus; dorsal fin entire; not more than 50 incisiform teeth in lower jaw, firmly attached, only slightly movable; dorsal rays XII, 16-18; anal rays II, 17-20; two cirri on each anterior nostril, the upper one longer and simple, the lower one sometimes bifid. . . . . *Ecsenius hawaiiensis*
- 8a. A pair of cirri present on each side of nape, the mesial one larger and usually multifid, the lateral one slender and simple or occasionally bifid (lateral cirrus sometimes lacking in juveniles); supraorbital cirrus multifid; upper lip crenulate; soft dorsal rays 14-16; anal rays II, 15-17. . . . .
- ... *Entomacrodus marmoratus*
- 8b. No cirri on nape; supraorbital cirrus simple; upper lip smooth; soft dorsal rays 18-23; anal rays II, 19-24. . . . . 9
- 9a. Adults and juveniles over 50 mm. in length with a median membranous crest on head, and with last soft dorsal ray attached to uppermost caudal rays by a membrane; no canines on dentary; dorsal rays usually XIII, 21-23, most commonly XIII, 22; anal rays II, 22 or 23; body tan to bluish black, frequently marked with light vertical bars; fins nearly uniformly dusky. . . . .
- ... *Istiblennius zebra*
- 9b. No crest on head; last soft dorsal ray free from caudal fin; a short canine posteriorly on dentary; dorsal rays XIII, 19-21, usually XIII, 19 or 20; anal rays II, 19-21; body tan, variously covered with light and dark spots; vertical fins spotted. . . . . *Istiblennius gibbifrons*
- 10a. Trunk and tail uniform deep brownish black or jet black; head and dorsal fin of males dark gray and marked with black lines or spots; dorsal and anal fins united to caudal by membranes (except in small juveniles); length rarely greater than 1 inch. . . . .
- ... *Enchelyurus brunneolus*

- 10b. Trunk and tail not uniformly colored but marked with dark stripes, lines, or bars on a lighter background; dorsal and anal fins not united to caudal; adult length 2–4 inches . . . . . 11
- 11a. Isthmus and throat pale, crossed by 5 or 6 dark V-shaped lines which are continued on cheeks; a dark spot, about size of eye, behind eye; body tan or yellowish, marked with about 11 oblique and vertical dark bars; a stout canine on each side of upper and lower jaws; pectoral rays 13 . . . . .  
 . . . . . **Omobranchus elongatus**
- 11b. Isthmus and throat pale, not crossed by dark lines; no dark spot behind eye; color pattern consisting of a dark lengthwise stripe, or stripes, against a lighter background; canines limited to lower jaw; pectoral rays 12 . . . . . 12
- 12a. A pair of black-edged blue stripes running length of body but not extending onto caudal fin; upper stripe narrow, passing dorsal to eye; lower stripe broad, passing ventral to eye; rest of body gray (brick-red in life); anal rays II, 32 or 33 . . . . . **Runula ewaensis**
- 12b. No black-edged blue stripes present; upper half of head and body brown, lower half abruptly white; brown area divided into two lengthwise stripes by a narrow white line running from snout across upper edge of eye to caudal peduncle; lower brown stripe frequently bearing dark blotches along its length; anal rays II, 29 or 30 . . . . .  
 . . . . . **Runula goslinei**, n. sp.

Family TRIPTERYGIIDAE  
Genus TRIPTERYGION Risso

*Tripterygion* Risso (1826: 241). Type of genus, *Tripterygion nasus* Risso.  
**Tripterygion atriceps** Jenkins  
*Tripterygion atriceps* Jenkins (1903: 505, type locality Honolulu).

*Enneapterygius atriceps*. Jordan and Evermann (1905: 19, 27, 496); Jordan and Seale (1906: 416); Fowler (1922: 84); Fowler and Ball (1925: 28); Pietschmann (1930: 20).  
*Enneapterygius atripes* Jordan and Jordan (1922: 82).  
*Enneapterygius hemimelas*. Fowler and Ball (1925: 28); Fowler (1927a: 29; 1928: 427; 1934: 445; 1938: 300; 1949: 145, in part); Pietschmann (1938: 44); Tinker (1944: 341); Edmondson (1946: 352).

This diminutive blenny has frequently been considered synonymous with the Samoan *T. hemimelas* Kner and Steindachner (1866: 371) to which it is closely related. Although the type of *hemimelas* was not seen, 20 specimens from Samoa and the neighboring islands of Tau and Rose were examined, and meristic data from these specimens and Hawaiian *atriceps* are presented in Table 1. These data may be summarized by saying that *atriceps* averages about one ray more than *hemimelas* for the anal and second and third dorsal fins, and that it also has more notched scales in the posterior lateral line. Males of both species differ from females in that their heads are black whereas those of females are relatively pale. Male *atriceps* have dark lips and their bodies are marked with a series of 9–14 dusky vertical bars which are frequently interrupted on the mid-sides and are sometimes fused to form about 6 bars dorsally. In male *hemimelas* the upper lip is dusky anteriorly and pale posteriorly, and the dusky body pigmentation is localized as a very broad vertical bar beneath the soft dorsal and another across the caudal peduncle. Female *atriceps* have the barred pattern of males but lack the black head pigmentation; female *hemimelas* are marked with only a few scattered dark pigment spots. In light of these differences *T. atriceps* is regarded as distinct from *T. hemimelas*.  
Chapman and Schultz (1952: 528), believing *atriceps* and *hemimelas* synonymous, reported a specimen of *hemimelas* from a barge



hauled from Guam to Pearl Harbor and there placed in drydock. This specimen (USNM No. 112290) was examined and found to be neither *atriceps* nor the Guamanian form (undescribed, and here based on USNM No. 123931). The barge specimen appeared to be most similar to typical Rose Island and Samoan *hemimelas*, and it is possible that this species is now established in Hawaii. In view of our limited knowledge of this barge's itinerary it is perhaps unwise to ascribe specific locales to specimens taken from it (cf. *Ecsenius hawaiiensis*).

*T. atriceps* is apparently an endemic Hawaiian blenny. It is abundant but seldom seen alive because of its habit of secreting itself in crevices in shallow reefs. Specimens may be obtained by splitting masses of coral rock or by the use of rotenone.

MATERIAL EXAMINED: *T. atriceps*—holotype and 6 paratypes at USNM; 15 Oahu at UH; 5 Oahu and 21 Hawaii in writer's collection. *T. hemimelas*—1 Apia, 8 Tutuila, 5 Rose Is., 6 Tau Is. at USNM.

Family BLENNIIDAE

Genus EXALLIAS Jordan and Evermann

*Exallias* Jordan and Evermann (1905: 503).  
Type of genus, *Salarias brevis* Kner.  
*Gloriella* Schultz (1941: 17), based on Ternate material.  
*Leoblennius* Reid (1943: 382).

*Exallias brevis* (Kner)

*Salarias brevis* Kner (1868*a*: 29; 1868*b*: 334, pl. 6, fig. 18, type locality Savay, Samoa); Fowler (1901: 518); Jenkins (1903: 506).  
*Salarias leopardus* Day (1869: 518), Ceylon material.  
*Blennius leopardus* Day (1876: 325), Hawaii and Ceylon material.  
*Alticus brevis*. Jordan and Evermann (1905: 17).  
*Exallias brevis*. Jordan and Evermann (1905: 503); Jordan and Seale (1906: 431); Jordan

TABLE 1  
COUNTS MADE ON SPECIES OF *Tripterygion*

		<i>T. atriceps</i> (HAWAII)	<i>T. hemimelas</i> (SAMOAN AREA)
Dorsal fin	III	48	16
	XII		2
	XIII	4	14
	XIV	41	
	XV	3	
	8	4	
	9	23	14
	10	21	2
Anal fin	I	48	18
	16		2
	17		9
	18	5	7
	19	35	
	20	8	
Pectoral fin (both sides counted)	14	1	3
	15	27	20
	16	24	13
Pore-bearing scales in anterior lateral line	16	3	1
	17		6
	18	11	1
	19	9	4
	20	4	
Notched scales in posterior lateral line	16	3	3
	17	3	4
	18	9	
	19	7	1
	20	2	

and Jordan (1922: 83); Strasburg and Schultz (1953: 128).  
*Cirripectes brevis*. Fowler (1922: 84; 1928: 432; 1938: 300; 1949: 149); Tinker (1944: 342).  
*Cirripectes leopardus*. Schultz (1941: 18; 1943: 272); Fowler (1949: 149).  
*Cirripectus leopardus*. Norman (1943: 810); Chapman, in de Beaufort and Chapman (1951: 247).  
*Cirripectus brevis*. Norman (1943: 810).  
*Leoblennius schultzi* Reid (1943: 382); Fowler (1949: 148).

The confusion regarding the names *brevis* and *leopardus* has been corrected by Strasburg and Schultz (1953), and to their synonymy

must also be added *Leoblennius schultzi* Reid (1943: 382). The holotype of *L. schultzi* was examined and found to be a late larval stage of *E. brevis*. A similar larva formed the basis for Schultz's earlier genus *Gloriella*.

*E. brevis* is a handsomely marked but rather uncommon blenny in Hawaii. As noted in the key, its color pattern consists of clusters of dark spots on a light background. In most fresh specimens the ground color is white or creamy, and the spots range from brown to almost black. In mature males the spongy pads covering the anal spines are deep indigo. Most specimens have been obtained from depths of 4–10 feet, but a series of three large males was taken at 20–35 feet off Waikiki on December 31, 1952. These males differed from others in that they were bright reddish orange marked with brown spots. It is possible that this vivid coloration is associated with habitat or perhaps breeding, since masses of blenny (?) eggs were found nearby.

Little is known of the habits of this fish. All but one of the mature specimens examined were taken by the use of rotenone; the exception was speared in shallow water. The species is widespread throughout the Indo-Pacific but is apparently nowhere common.

MATERIAL EXAMINED: Holotype of *Leoblennius schultzi*, 1 other Oahu, 5 "Hawaii," and 3 Johnston Is. at USNM; 1 Oahu at BPBM; 5 Oahu, 2 Kauai, 1 Hawaii, and 1 Johnston Is. at UH; 1 Lanai at POFI; 2 Hawaii at DFG.

#### Genus CIRRIPECTUS Swainson

*Cirripectus* Swainson (1839: 79–80, *Cirripectes* on pp. 182, 275). Type of genus, *Salarias variolosus* Valenciennes.

#### *Cirripectus obscurus* (Borodin)

*Cirripectes alboapicalis*. Fowler (1923: 389; 1927b: 91; 1928: 433; 1938: 300); Tinker (1944: 342).

*Exallias obscurus* Borodin (1927: 1, type locality Oahu).

*Exallias obscurus* Borodin (1928: 53).

*Cirripectes obscurus* Borodin (1928: 54).

*Cirripectes variolosus*. Schultz (1941: 20, in part); Fowler (1949: 148, in part).

*Cirripectus variolosus*. Chapman, in de Beaufort and Chapman (1951: 250, in part).

In a report on the fishes of Lord Howe Island, Ogilby (1899: 742) described *Salarias alboapicalis* as new, the species being characterized and named because of a conspicuous white patch located anteriorly and distally on the spinous dorsal fin. McCulloch and McNeill (1918: 23), although disagreeing with Ogilby on other characters of the species, present a figure of a Lord Howe specimen which clearly shows the fin-marking noted by Ogilby. While these records are extralimital to the present study they are worthy of note in that the descriptions and figures come very close to fitting a common Hawaiian blenny. This fish was initially identified as *C. alboapicalis* by Fowler (1923: 389) but later described as a new species, *Exallias obscurus*, by Borodin (1927: 1), both names ultimately being relegated to the synonymy of *C. variolosus*.

Dr. Gilbert P. Whitley of the Australian Museum has kindly examined all specimens referable to *Cirripectus* in that institution. His counts on the Lord Howe cotypes of *alboapicalis* (the holotype is lost) are in close agreement with those obtained from Hawaiian material, but the fading of his specimens precludes adequate color notes. In any case both the Lord Howe *alboapicalis* and the Hawaiian form are quite distinct from *variolosus*, and further, appear to be separable themselves. The holotype of *C. obscurus* (Borodin) and numerous other Hawaiian specimens referable to that species have been examined, and in none of them is the dorsal fin characterized by the white membrane shown by McCulloch and McNeill (1918: pl. 4). Furthermore, no specimens of *obscurus* show any



indication of white spotting on the anal fin as depicted for *alboapicalis* by these authors. It is felt that these differences in coloration warrant the separation of *obscurus* from *alboapicalis* until such time as fresh Lord Howe material is available.

The color pattern of *C. obscurus* is somewhat variable, a 113 mm. freshly-killed male being marked as follows: head and anterior trunk rose, shading to rosy brown, covered with small white dots; posterior trunk and tail dark brown, covered with scattered white dots, and with a series of eight broken olive bars on sides; first dorsal rosy; second dorsal dusky rose shading to purple; anal indigo; pectorals purple; caudal rose; nuchal cirri dark blue; nasal and supraorbital cirri red; iris golden. A 94 mm. female had the body golden brown with darker mottlings and covered with small white dots; the fins and other structures were as in the male except that the anal fin bore two lengthwise red stripes.

*C. obscurus* is probably the largest and among the most colorful of the Hawaiian blennies. Specimens of standard lengths up to 135 mm. are common over rocky bottoms at depths of from 4 to 20 feet. The species must be regarded as an Hawaiian endemic for the pres-

ent. Its affinities appear to lie with *alboapicalis* and also with an as yet undescribed blenny (USNM Nos. 65412 and 65413) from Easter Island.

MATERIAL EXAMINED: Holotype of *C. obscurus* (Borodin) at AMNH; 30 Oahu, 7 Hawaii at UH; 39 Oahu in writer's collection.

*Cirripectus lineopunctatus*, new species

Fig. 1

HOLOTYPE: USNM No. 164198, a male, 59 mm. in standard length, taken in a shallow-water rotenone station at Kaena Point, Oahu, T.H., on March 19, 1950, by Gosline, Strasburg, Banner, and Sherman.

PARATYPES: USNM No. 164199, 8 specimens, 28–69 mm. in standard length, taken with holotype; USNM No. 164201, 5 specimens, 28–44 mm. in standard length, taken in a shallow-water rotenone station just north of Makapuu Point, Oahu, T.H., on Sept. 28, 1950, by Gosline and party; USNM No. 164200, 6 specimens, 36–62 mm. in standard length, taken in a rotenone station at depths of 5–30 feet, Hanauma Bay, Oahu, T.H., on Sept. 16, 1951, by Gosline and Holland.

It is probable that, if previously taken, this

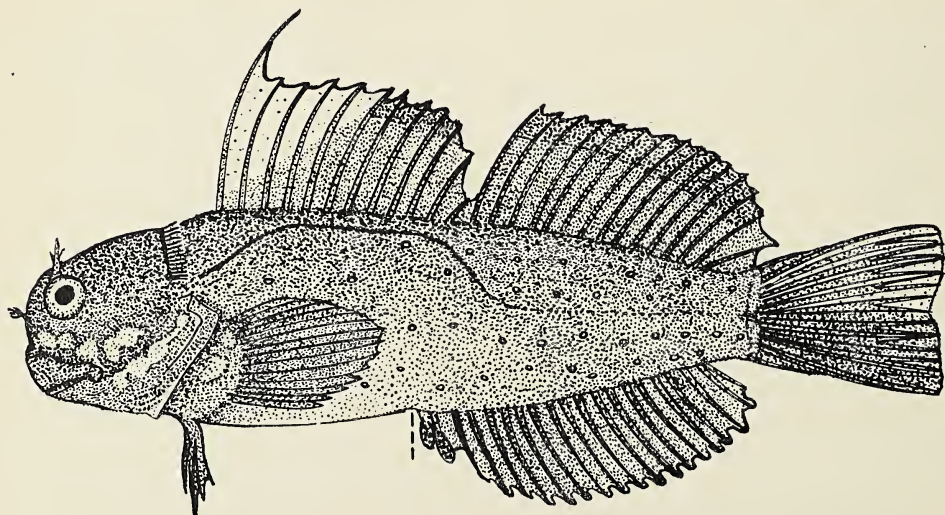


FIG. 1. Holotype of *Cirripectus lineopunctatus*, new species (USNM No. 164198) from Kaena Point, Oahu. Scale represents 20 mm.

species has been confused with either *C. obscurus* or *variolosus*. Fowler (1941: 276) reports a specimen of *variolosus* from Waianae, Oahu, which is marked somewhat as *lineopunctatus*. His description is inadequate for definite identification, and the specimen has not been seen.

**DESCRIPTION:** Counts made on *lineopunctatus* are recorded in Table 2, and detailed measurements, expressed in thousandths of the standard length, appear in Table 4.

Dorsal rays XII, 15 (very rarely 16); anal II, 15–17 (rarely 15 or 17), first anal spine embedded in females; pectoral 15; pelvics I, 4; branched caudal rays 5+4; fringe of cirri on nape 25–32; nasal cirri 3–6, usually 5; supraorbital cirri usually slender and unbranched, or if branched, branches arise from a central axis and never number more than 5.

Head 3.5 or 3.6; greatest depth 3.2–4.1; longest dorsal spine 3.3–5.4 (spine elongate in mature males); longest pectoral ray 4.6–5.1; all in the standard length. Eye 4.1–4.7; snout 2.9–3.3; interorbital space 8.3–9.3; postorbital length of head 1.5; least depth of body 2.4–2.7; greatest depth of body 0.9–1.1; all in length of the head; snout 1.2–1.4 in least distance between eye and nuchal fringe.

Supraorbital cirrus commonly a simple tapered flap; in some specimens a few branches arise from near its base, but cirrus base is never notably enlarged (as in *C. obscurus* and *variolosus* where it resembles a candelabrum); nuchal band of cirri interrupted on mid-dorsal line, extending ventrally to level of pupil, cirri usually simple; snout profile nearly vertical; edge of upper lip with about 35–40 short fleshy papillae; lower lip plicate laterally, weakly papillate mesially, and with a short flap lateral to plicate portion; lateral line arched over pectoral fin, then running along midsides to base of caudal; tip of depressed pectoral just reaches anus; anal spines two, first embedded in mature females, both enclosed in convoluted pads of fleshy tissue in mature males; membrane between eleventh dorsal spine and first soft ray deeply notched,

minute twelfth dorsal spine at base of notch; membranous attachment of last dorsal ray to caudal peduncle ending directly above flexure marking caudal fin base; fifth pectoral ray from lowermost edge of fin longest; caudal fin subtruncate, occasionally slightly concave; a curved canine present posteriorly on dentary; incisiform teeth in both jaws very numerous, of equal size, and freely movable.

**Color in alcohol.** Ground color light to dark brown; trunk and tail with 3–5 irregular lengthwise rows of light dots, many of which are rimmed with black; a few black dots posteriorly on tail; cheeks, snout, upper lip, and pectoral bases brown, irregularly marbled with white; throat and belly brown; dorsal fin blackish, sometimes a few white dots on posterior part; membrane between first few dorsal spines unpigmented and transparent distally, line of demarcation between pigmented and pale portions running from base of first spine to tip of about sixth spine; anal fin plain blackish or with a few white dots in males, abundantly spotted with white in females; tissue covering anal spines of males grayish; lower lobe of caudal blackish in males, spotted with white in females; upper lobe of caudal white or gray in both sexes; pectorals brownish with weak indications of white spotting in both sexes; pelvics brown; nuchal, supraorbital, and nasal cirri dusky.

**Color in life.** Head, body, and fins dark brown; cheeks, upper lip, and pectoral bases mottled with light olive; body covered with small black-rimmed white or yellow dots arranged in lengthwise rows and frequently aligned vertically; small black dots, also arranged in rows, sometimes present; dorso-anterior part of spinous dorsal red; nuchal cirri blackish; supraorbital cirri red or black; nasal cirri red.

**RELATIONSHIPS:** *C. lineopunctatus* is most closely related to *C. quagga*. The latter was described from Wake Island (Fowler and Ball, 1924: 273) but has also been taken throughout the Indo-Pacific region (Chapman, in de Beaufort and Chapman, 1951:



255). By comparing the description of *lineopunctatus* with that of *quagga* given by Strasburg and Schultz (1953) it is apparent that the two have the following characters in common: about the same number of nuchal cirri and dorsal, anal, and pectoral rays; a simple or occasionally multifid supraorbital cirrus; a high ratio for the least distance between the eye and nuchal fringe compared to the snout length; and a color pattern in part composed of light and dark dots on a brown background. Examination of fresh specimens of *quagga* obtained by Gosline and Randall at Wake in 1953 shows that the two forms are separable as follows. In *quagga* two dark lines extend transversely across the throat and are continued on the cheeks and suborbital regions; in *lineopunctatus* the throat is uniform brown. In *quagga* the sides are marked with 10–16 dark vertical bars, these being very distinct in light-colored specimens but obsolescent in dark or large individuals, with some indications persisting in all but the most melanistic specimens. In *lineopunctatus* there is never any indication of dark bars on the sides from standard lengths of 29 to 69 mm. In *quagga* the white dots on the sides are not rimmed in black (based on preserved material and Fowler's figure [1928: 437]), while in *lineopunctatus* they are. There are also minor tendencies for the mean dorsal and anal ray counts to be greater in *lineopunctatus*, while the mean number of its nuchal cirri is slightly less than in *quagga*.

So far as known, *C. lineopunctatus* is limited to Hawaii and Johnston Island. The species is moderately common at depths of 4–10 feet, and occurs in rocky areas subject to a fairly strong surf. It has been named *lineopunctatus* in reference to the lengthwise rows of dots on the body.

MATERIAL EXAMINED: Holotype, paratypes, and 7 Johnston Is. at USNM; 5 Oahu and 3 Johnston at UH.

### *Cirripectus variolosus* (Valenciennes)

*Salarias variolosus* Valenciennes, in Cuvier and

Valenciennes (1836: 317, type locality Guam); Fowler (1901: 518); Jenkins (1903: 507).

*Alticus variolosus*. Jordan and Evermann (1905: 17, 497); Jordan and Seale (1906: 424).

*Cirripectes variolosus*. Fowler (1922: 84; 1928: 433; 1938: 243, 300; 1949: 148); Tinker (1944: 342); Edmondson (1946: 352).

*Rupiscartes variolosus*. Jordan and Jordan (1922: 83); Fowler and Ball (1925: 29).

*Cirripectes alboapicalis*. Pietschmann (1938: 44).

*Ophioblennius vanderbilti* Fowler (1938: 242, 300; 1949: 148); Reid (1943: 380).

*Ophioblennius capillus* Reid (1943: 381); Fowler (1949: 148).

*Cirripectus variolosus*. Fowler (1941: 276); Chapman, in de Beaufort and Chapman (1951: 249).

Its wide distribution and number of close relatives has caused *C. variolosus* to present a confusing taxonomic picture, part of which was corrected by Strasburg and Schultz (1953). Like *Exallias brevis* this blenny has distinctive larval stages which have been the basis for the erection of *Ophioblennius vanderbilti* and *O. capillus*. Chapman (in de Beaufort and Chapman, 1951: 251), correctly synonymized *O. vanderbilti* with *variolosus* but apparently overlooked Reid's *O. capillus*. The holotype of this species was examined and found to be another large larva of *C. variolosus*. The dentition differences between it and *O. vanderbilti* noted by Reid (*op. cit.*: 382) are probably ascribable to damage or to its greater ontogenetic age. Pietschmann's record of *C. alboapicalis* (1938: 44) from Pearl and Hermes Reef is obviously based on specimens of *C. variolosus*.

*Color in life*: head brown, with or without bright red markings; body olive-brown to deep brownish black, often with a blue or purple sheen; upper portions of dorsal and caudal fins red, rest of these fins blackish; anal fin deep blue-black; nasal and supraorbital cirri either red or brown; nuchal cirri brown. In preservative, red markings dis-

appear from head, and red fin membranes become colorless or white, leaving specimens uniform leather-brown or blackish.

*C. variolosus* is one of the most numerous Hawaiian blennies, being taken in nearly every rotenone station at depths of from 2 to 30 feet. It abounds particularly on the shallow

TABLE 2  
COUNTS MADE ON HAWAIIAN SPECIES OF *Cirripectus*

		<i>C. obscurus</i>	<i>C. lineopunctatus</i>	<i>C. variolosus</i>
Dorsal fin	XI	1		
	XII	76	35	114
	13			1
	14			108
	15	4	34	5
	16	73	1	
Anal fin	II	77	35	114
	14			4
	15	1	1	107
	16	11	30	3
	17	65	4	
Pectoral fin (both sides counted)	13			1
	14	1	1	
	15	85	53	51
	16	2		1
Total nuchal cirri	25-26		5	
	27-28		15	
	29-30		12	
	31-32		3	6
	33-34			17
	35-36			25
	37-38	9		42
	39-40	20		15
	41-42	26		6
	43-44	16		1
	45-46	2		
Supraorbital cirri (both sides counted)	1		62	
	2		3	1
	3		2	4
	4	4	2	12
	5	43	1	41
	6	67		54
	7	23		61
	8	5		35
	9			9
	10			3
	11			1

“dead” reefs such as characterize Waikiki, and a swimmer may see numerous specimens flitting in and out of crevices. The species is widespread throughout the Indo-Pacific area.

MATERIAL EXAMINED: Holotype of *O. capillus* at USNM; 28 Oahu, 3 Kauai, 51 Johnston, 2 French Frigate Shoals, and 4 Midway at UH; 1 Maui and 1 Hawaii at POFI; 23 Oahu in writer’s collection.

Genus ENTOMACRODUS Gill

*Entomacrodus* Gill (1859: 168). Type of genus, *Entomacrodus nigricans* Gill.

**Entomacrodus marmoratus** (Bennett)  
Fig. 2

*Blennius marmoratus* Bennett (1828: 35, type locality Sandwich Islands).

*Salarias marmoratus*. Günther (1861: 248, 562; 1877: 204, but not pl. 116, fig. B); Jenkins (1903: 507); Snyder (1904: 536); Fowler (1927a: 29, in part; 1928: 435, in part; 1934: 445, in part; 1938: 243, 300, in part; 1940: 794; 1941: 276; 1949: 149, in part); Galtsoff (1933: 20); Tinker (1944: 342, but not his figure).

*Alticus marmoratus*. Jordan and Evermann (1905: 5, 7, 10, 23, 498, but not fig. 220); Jordan and Seale (1906: 424); Fowler (1922: 84).

*Rupiscartes marmoratus*. Jordan and Jordan (1922: 83); Fowler and Ball (1925: 29, in part).

*Salarias meleagris*. Fowler (1923: 389; 1928: 440; 1938: 301; 1949: 150); Tinker (1944: 344); Edmondson (1946: 352).

*Rupiscartes striatus*. Fowler and Ball (1925: 28).

*Istiblennius marmoratus*. Norman (1943: 812).

*Entomacrodus marmoratus*. Chapman, in de Beaufort and Chapman (1951: 272, 283, 285).

Although Norman (1943: 807) was the first to properly define the genus *Entomacrodus* he failed to place *marmoratus* and other



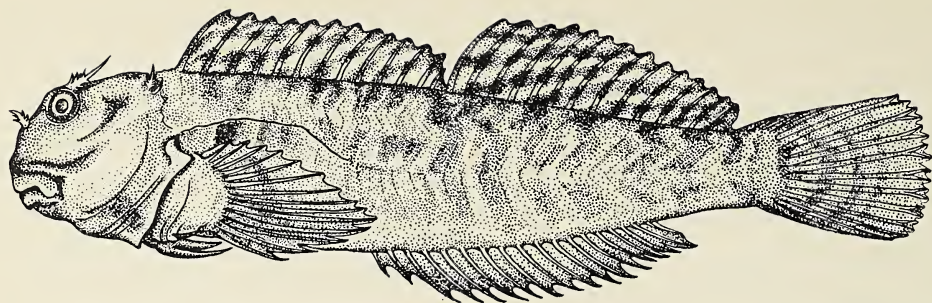


FIG. 2. *Entomacrodus marmoratus* (Bennett), based on a specimen 95 mm. in standard length from Hanauma Bay, Oahu.

congeners in it, probably because of difficulty in determining the presence of vomerine teeth, the salient generic character. Chapman (de Beaufort and Chapman, 1951: 272), discusses six Indo-Australian species of *Entomacrodus*, and also mentions seven others, including *marmoratus*, from other parts of the Pacific and the tropical Atlantic. The recorded distribution of *marmoratus* covers much of the Indo-Pacific, but both Chapman's work and the manuscripts for the Bikini studies demonstrate that the non-Hawaiian records are based on other species. It has not been possible to investigate many records extra-limital to this study, but both Fowler and Ball's record from Wake Island (1925: 29) and Smith's from South Africa (1950: 508, pl. 75) were seen and found to be other species. Fowler's records of *S. meleagris* from Hawaii (see synonymy) were also checked and found to be based on specimens of *marmoratus*. It should be noted that neither Günther's figure (1877: pl. 116, fig. B), Jordan and Evermann's (1905: fig. 220), nor Tinker's (1944: 343) actually represent *marmoratus*. Figure 2 is here supplied as an illustration of this blenny.

As noted in the key, the quickest method of identifying *E. marmoratus* is by the presence of two (sometimes only one in juveniles) cirri on each side of the nape. The lateral member of each pair is a short simple filament while the mesial one is commonly multifid. Unfortunately, only the mesial cirrus is clearly visible in Figure 2. The presence of vomerine

teeth, while of considerable taxonomic importance, is hardly useful in routine species determination. Dissection and staining are almost necessities to see the series of about a dozen minute conical teeth on the vomer. Other distinguishing characters are presented in the key.

The mottled color pattern of *marmoratus* is well shown in Figure 2 but the actual colors involved are rather variable. The dark blotches are a rich brownish black in life and the belly is pure white. The ground color of the rest of the fish consists of various shades of olive-brown, brownish pink, or olive-green, with olive-brown the most common.

*E. marmoratus* abounds in areas of heavy surf such as occur along the rocky shores of the Hawaiian Islands. It is commonly seen leaping into the surf or skittering across the surface of rough water. Specimens are easily obtained by the use of rotenone, by pole-fishing using tiny hooks, or by scoop net. The species is endemic to Hawaii and appears to be most closely related to *E. epalzeocheilos* (Bleeker) of the East Indies, Indian Ocean, and Samoa. Distinguishing features of *epalzeocheilos* are given by Chapman (de Beaufort and Chapman, 1951: 274, 281).

MATERIAL EXAMINED: 16 Hawaiian Is., 5 Oahu, 9 Molokai at USNM; 35 Midway at UH; 1 Laysan, 2 Oahu at BPBM; 7 Lanai, 5 Oahu, 3 Hawaii, 31 Maui at POFI; 1 Hawaii at DFG; 108 Oahu in writer's collection.

## Genus ISTIBLENNIUS Whitley

*Istiblennius* Whitley (1943: 185). Type of genus, *Salarias mulleri* Klunzinger.

This genus, as here understood, includes those blennies which possess the following characters: teeth (excluding canines) freely movable in both jaws; trunk lateral line well developed; ventral rays I, 2 or 3; branched caudal rays 5 above plus 4 below except in very young; a tentacle over each eye; spinous and soft dorsal separated by a distinct notch in their connecting membrane. Its species lack the following characters possessed by related genera: transverse fringe of nuchal cirri, sucking appendage on lower lip, elongate anterior anal rays, vomerine teeth, and membranous connection of last anal ray to caudal peduncle. Even with the above restrictions the genus is probably heterogeneous, and has been described by Norman (1943: 811) as a "... large and varied assemblage of species."

Members of *Istiblennius* have been observed by the writer in the Hawaiian, Marshall, and Gilbert Islands, and were found to fall into two natural groupings on morphological and ecological grounds. In one group a stout canine tooth is present posteriorly on the dentary and there is a prominent bulging of the forehead so that the snout slopes backward from the eye to the mouth. Species included here are *I. gibbifrons* in Hawaii and *I. paulus* and *coronatus* in the Central Pacific. All three characteristically occur on submerged reefs at depths of from 1 to 4 feet, and they rarely frequent supratidal habitats.

The second group of species lacks the canine teeth and bulging forehead of the first, and includes *I. zebra* in Hawaii and *I. edentulus* and *lineatus* of the Central Pacific. All of these are found in either supra- or intertidal pools and only rarely on submerged reefs. A study of *zebra* and the descriptions of eight other members of the second group listed by Chapman (de Beaufort and Chapman, 1951), indicates other phyletic tenden-

cies which are probably sufficiently strong to warrant the separation of the two groups as distinct subgenera or genera. As noted in the introduction, however, it is felt that such separation should not be attempted outside of monographic treatment, and thus is not included here.

*Istiblennius zebra* (Vaillant and Sauvage)

*Salarias zebra* Vaillant and Sauvage (1875: 281, type locality Sandwich Islands); Snyder (1904: 536); Jordan and Evermann (1905: 501); Jordan and Seale (1906: 426); Jordan and Jordan (1922: 83); Fowler and Ball (1925: 29); Fowler (1927a: 30; 1928: 439; 1934: 446; 1938: 244, 301; 1940: 796; 1941: 276; 1949: 150, in part); Pietschmann (1938: 45); Tinker (1944: 344); Edmondson (1946: 352).

*Salarias edentulus*. Fowler (1901: 517; 1922: 84; 1928: 438, in part; 1938: 301; 1949: 150); Steindachner (1901: 499, 520); Jordan and Evermann (1905: 15, 17, 503); Jordan and Jordan (1922: 83); Tinker (1944: 343); Chapman, in de Beaufort and Chapman (1951: 331).

*Salarias cypho* Jenkins (1903: 506).

*Scartichthys zebra*. Jordan and Evermann (1905: 11, 19).

*Alticus zebra*. Jordan and Evermann (1905: 24, 27).

*Istiblennius zebra*. Norman (1943: 812); Strasburg (1955: 299).

As pointed out by Strasburg (1955: 299) there has been some confusion in the literature with respect to *I. zebra* and *I. edentulus* (Bloch, in Bloch and Schneider, 1801: 172), and the two are undoubtedly closely related. The fin ray counts of Hawaiian "*edentulus*" given by Steindachner (1901: 499) are sufficiently complete to show that he dealt with *zebra*, and some Hawaiian *edentulus* listed by Fowler (1928: 438) have been examined and also found to be *zebra*. Other specimens of *edentulus* from Hawaii (Fowler, 1901: 517; 1922: 84; 1938: 301; and Tinker, 1944: 343–



344) have not been seen, and their taxonomic status is subject to some doubt. Records of *zebra* from Tahiti (Fowler, 1949: 150) and the Tuamotus (Harry, 1953: 134) are possibly based on a species still undescribed but perhaps identical to one noted by Chapman (de Beaufort and Chapman, 1951: 331), from the Marquesas.

Among Hawaiian blennies, *I. zebra* is unique in its possession of a high fleshy crest along the midline of the head. This crest is present in both sexes at lengths greater than 50 mm., but appears earlier and attains a greater size in males. Specimens too small to have the crest could be confused only with *I. gibbifrons*, *E. marmoratus*, or perhaps *Omobranchus elongatus*. Separation from these can be accomplished by the fact that *zebra* has no canine teeth, lacks nuchal cirri, and has a notched dorsal fin.

Life coloration of adult *zebra* varies from bluish black through gray to yellowish brown, the sides commonly being marked with a series of gray or tan vertical bars. In large specimens the fins may be irregularly blotched with red, and in males the cheeks may be dull orange.

This blenny abounds in pools on rocky coasts, being particularly common on Oahu along the Koko Head coast, on Rabbit Island, and on the rocky shores between Waimea and Kaena Point. It is generally restricted to supra- or inter-tidal pools, and was taken only twice by the writer from submerged reefs. The species is not known from Midway or Johnston islands, probably because of a lack of suitable habitats, but may otherwise be regarded as endemic to the Hawaiian area.

MATERIAL EXAMINED: 34 Oahu, including holotype of *Salarias cypho*, 31 Necker, 31 Laysan, 24 Hawaii, 30 Maui, and 3 "Hawaiian Islands" at USNM; 1 Maui, 4 Hawaiian Islands at MCZ; 87 Oahu in writer's collection.

### *Istiblennius gibbifrons* (Quoy and Gaimard)

*Salarias gibbifrons* Quoy and Gaimard (1824:

253, type locality Hawaiian Islands); Valenciennes, in Cuvier and Valenciennes (1836: 312); Günther (1861: 251; 1877: 205); Fowler (1901: 517; 1928: 437; 1934: 446; 1938: 243, 301; 1949: 150); Snyder (1904: 536); Pietschmann (1938: 45); Tinker (1944: 343); Chapman, in de Beaufort and Chapman (1951: 342, in part).

*Salarias saltans* Jenkins (1903: 508).

*Salarias rutilus* Jenkins (1903: 509).

*Alticus gibbifrons*. Jordan and Evermann (1905: 4, 10, 17, 19, 27, 499); Jordan and Seale (1906: 423); Fowler (1922: 84).

*Entomacrodus gibbifrons*. Jordan and Evermann (1905: 23).

*Rupiscartes gibbifrons*. Jordan and Jordan (1922: 83); Fowler (1925: 30); Fowler and Ball (1925: 29).

*Salarias periophthalmus*. Fowler (1928: 439, in part).

*Istiblennius gibbifrons*. Norman (1943: 812).

*Blenniella rhessodon* Reid (1943: 383); Fowler (1949: 148).

Dissimilarities between various growth and sexual forms of *gibbifrons* have resulted in males and females being described as separate species (Jenkins, 1903) and a larval stage as a new genus and species (Reid, 1943). Sexual dimorphism was clarified by Snyder (1904), and the writer's examination of the holotype of *Blenniella rhessodon* revealed it to be a late larval stage of *I. gibbifrons*. Fowler (1928: 439) lists MCZ as having Hawaiian specimens of *Salarias periophthalmus*, but upon examination these proved to be *I. gibbifrons*.

*I. gibbifrons* has been widely recorded from the Pacific Ocean, but Chapman (de Beaufort and Chapman, 1951: 344), limits its certain distribution to Hawaii and adjacent regions. Unpublished work on the blennies of the northern Marshall Islands by Schultz and Chapman indicates that a closely related Marshallese form is specifically distinct, but the writer's examination of specimens from Wake Island (only 500 miles north of Bikini) showed them to be indistinguishable from

the Hawaiian form. The Hawaiian form is also abundant at Johnston Island, but no specimens were found in a collection from Palmyra. In view of these circumstances, *gibbifrons* may probably be regarded as limited to the area immediately around the Hawaiian Islands.

Jenkins' figures (1903: 503–509) are duplicated by Jordan and Evermann (1905: 499–500) and give an excellent representation of the color pattern of the two sexes of *gibbifrons* ("saltans" is a male, and "rutilus" a female). Unfortunately, neither figure depicts the bulbous forehead characteristic of this group of blennies (see generic diagnosis). Life coloration consists of a pale olive or tan ground color overlaid with a network of fine golden-brown lines. Females bear a series of eight dusky bars on the trunk and tail but these are much less obvious in males. In males the sides are marked with rows of small bluish white ocelli, and the spinous dorsal is dusky distally. In females this duskiness is usually reduced to a single black spot in the membrane between the first two spines.

*I. gibbifrons* occurs on permanently submerged reefs at depths less than about 4 feet. It is common at Waikiki and also on limestone benches along the Waianae coast. The species is very alert and agile and can be taken easily only with rotenone. Large larvae are phototaxic and numerous specimens have been taken at night using an electric surface light.

MATERIAL EXAMINED: Holotype of *Bleniella rhessodon* at USNM; 7 Sandwich Islands at MCZ; 22 Midway, 22 Johnston, and 31 Oahu at UH; 1 French Frigate Shoals, 1 Nehoa, 1 Oahu, 3 Maui, 2 Hawaii at POFI; 35 Hawaii in writer's collection.

#### Genus ECSENIUS McCulloch

*Ecsenius* McCulloch (1923: 121). Type of genus, *E. mandibularis* McCulloch.

*Ecsenius hawaiiensis* Chapman and Schultz

*Ecsenius hawaiiensis* Chapman and Schultz (1952: 526, type locality Pearl Harbor, Oahu).

The peculiar circumstances leading to the capture of the only known specimens of this blenny have been mentioned in the discussion of *Tripterygion atriceps*. Suffice it to say that fish living in the fouling on the bottom of a barge brought to Hawaii from Guam may not necessarily be Hawaiian species. Chapman and Schultz's statements (1952: 528) concerning the Hawaiian nature of the barge's fauna have been shown to be in error for *Tripterygion*, and may also be so for *Ecsenius*. Regardless of its geographic origin, however, *E. hawaiiensis* may now have established itself on Oahu, and is therefore included in this report.

*E. hawaiiensis* may be quickly distinguished from other Hawaiian blennies by its lack of supraorbital cirri and by the fact that the teeth in the upper jaw are freely movable, whereas those in the lower jaw are fixed. Mr. Kenneth Wong, formerly of the Honolulu Aquarium, noted that living specimens of the type series of *E. hawaiiensis* were purple anteriorly and yellow posteriorly. Preserved specimens are plain olive or brownish, with no indication of this regional color differentiation. The vertical white bars noted on the sides by Chapman and Schultz (1952: 527) are not present on all specimens, and these authors' figure does not clearly depict the basal black spot between the first three dorsal spines. Other distinguishing characters are given in the key.

Little is known concerning the biology of the genus *Ecsenius* aside from Chapman and Schultz's general statements of its occurrence at moderate depths as opposed to shallow reefs. If it is normally a deep water form it is possible that specimens of *E. hawaiiensis* will not be taken for some time, even if well established in the Hawaiian area. So far as known, the species has been taken only from the Hawaiian Islands.



MATERIAL EXAMINED: Holotype and 12 paratypes at USNM; 1 Oahu taken with the type series and retained at UH.

### Genus ENCHELYURUS Peters

*Enchelyurus* Peters (1868: 268). Type of genus, *Enchelyurus flavipes* Peters.

In setting up *Enchelyurus*, Peters presents the following diagnostic characters: dentition and lack of scales as in *Petroscirtes*, gill opening as wide as pectoral base, and dorsal and anal fins united with the caudal. Norman (1943: 798) uses the united vertical fins as a major character, but further limits the genus to species with gill openings extending about half-way down the pectoral bases, even though his list of pertinent species (*op. cit.*: 804) includes *flavipes* which has much larger gill openings. The writer's examination of *flavipes*, *kraussi*, *ater*, *hepburni*, and *brunneolus* showed that *Enchelyurus*, as used by Norman, is not only poorly defined but probably also polyphyletic. A review of this and related genera is not possible at present, and the genus *Enchelyurus* is temporarily used for those blennies with no scales, fixed teeth, and united vertical fins.

### *Enchelyurus brunneolus* (Jenkins)

*Aspidontus brunneolus* Jenkins (1903: 510, type locality Honolulu); Snyder (1904: 536).

*Enchelyurus ater*. Jordan and Evermann (1905: 19, 27, 500); Jordan and Seale (1906: 434); Jordan and Jordan (1922: 83); Fowler (1925: 30; 1928: 443; 1934: 447; 1938: 301; 1949: 151); Fowler and Ball (1925: 29); Pietschmann (1930: 22; 1938: 50); Tinker (1944: 345).

*Enchelyurus edmondsoni* Fowler (1923: 389; 1928: 443-444; 1938: 301; 1949: 151); Norman (1943: 804); Tinker (1944: 345).

Jordan and Evermann synonymized *brunneolus* with the closely related *E. ater* (Günther, 1877: 199) in 1905. The latter species occurs

in the southeastern Pacific, and on the average differs from *brunneolus* of Hawaii as follows: *brunneolus* has 14 pectoral rays, *ater* has 15; in *brunneolus* the gill opening extends ventrally to the level of the fifth or sixth pectoral ray, in *ater* it extends to the eighth to tenth; *brunneolus* has 10 dorsal spines while *ater* has 9; and in *brunneolus* there are 19 or 20 soft anal rays whereas *ater* has 17-19. Dr. N. B. Marshall, of the British Museum, has kindly confirmed these findings for the holotype of *Petroscirtes ater* Günther.

Some sexual dimorphism occurs in *brunneolus*, the general picture being that females are uniform blackish brown or black, whereas in mature males the trunk and tail are black and the throat, gill membranes, and cheeks are gray with black spots and bars. In males the dorsal fin is traversed by a series of narrow black lines running posteriorly and dorsally; in females this fin is nearly uniform black with an intensely black spot between the first two spines. Finally, in mature males the anal fin is marked with two or three dark lengthwise stripes and the tips of the rays are somewhat enlarged and arrow-shaped. In females the anal fin is uniform black and the rays have a normal taper.

The holotype of Fowler's *E. edmondsoni* was examined and found to be a mature male *brunneolus*. The specimen is now a light brown and probably too discolored to permit an adequate color description to be made. Fowler's figure of the holotype of *edmondsoni* (1928: 444) is very misleading in that he shows the species to have dark markings on a white or very light background, whereas actually the ground color is quite dark and the markings even darker. The lengthwise bands on the trunk and tail shown by Fowler are neither mentioned in the type description (1923: 390) nor visible on the holotype.

The fact that this blenny is nearly jet black in color and rarely exceeds an inch in length makes it quite easy to recognize. It could be confused only with juvenile *Cirripectus*, but can be readily told from these by its lack of

nuchal and supraorbital cirri. Its united dorsal, caudal, and anal fins (except in the very young) also make it distinctive.

*E. brunneolus* is fairly common within the interstices of a dead coral reef, such as at Waikiki, and specimens may also be found clinging to the undersides of reef rocks. It is frequently overlooked in rotenone collecting because of its small size, but living specimens can be captured by splitting masses of coral-line rock. The species is endemic to the Hawaiian area.

MATERIAL EXAMINED: *E. brunneolus*, holotype of *Aspidontus brunneolus* at USNM; holotype of *Enchelyurus edmondsoni* at BPBM; 21 Oahu, 1 Kauai, 2 French Frigate Shoals, 1 Laysan at UH; 10 Maui at POFI; 6 Oahu in writer's collection.

*Enchelyurus ater*, 21 Samoa at USNM; holotype of *Petroscirtes ater* (from Tahiti) at British Museum (examined by Dr. N. B. Marshall).

#### Genus OMOBRANCHUS (Ehrenberg) Valenciennes

*Omobranchus* (Ehrenberg) Valenciennes, in Cuvier and Valenciennes (1836: 287). Type of genus, *Blennechis fasciolatus* Valenciennes (ex *Omobranchus fasciolatus* Ehrenberg MS).

#### *Omobranchus elongatus* (Peters) Fig. 3

*Petroscirtes elongatus* Peters (1855: 249, type locality Mossambique).

*Omobranchus elongatus*. Norman (1943: 804, undoubtedly based on non-Hawaiian material).

Although Hawaiian specimens of *Omobranchus* appear to fit Peters' description of *elongatus* there is some doubt as to whether they are actually that species. Color pattern differences, perhaps ascribable to sexual dimorphism, have resulted in considerable confusion between *elongatus* and *kallosoma* of Bleeker (1858: 227). The two species have

been synonymized by Günther (1877: 196) and Fowler (1928: 429) but regarded as distinct by Fowler (1949: 146) and de Beaufort (de Beaufort and Chapman, 1951: 374). A lack of comparative material has prevented a study of differences between these species, and the name *elongatus* is tentatively used because it fits fairly well and is the oldest available name.

The four known Hawaiian specimens of *O. elongatus* may or may not deserve a place in the fauna of the Hawaiian Islands. All were obtained from a concrete tank located on Coconut Island, Kaneohe Bay, Oahu, which has been figured by Tester (1952: 3). From Tester's photograph and description the following facts about this tank are of note. It is located on land but near water, its dimensions are about 11 by 35 feet with a depth of 4 feet, and it is supplied with running water from Kaneohe Bay by a submerged inlet and an overflow-type outlet. The biota of the tank normally consists of tuna, tunny, surgeon fish, and other moderately large experimental animals, a few small fish and crabs (which presumably enter with incoming water), and a variable growth of algae. During the spring of 1951 a number of pieces of coralline rock bearing *Tridacna* clams and undoubtedly other organisms were obtained from near the Samoan Islands and placed in the tank by the staff of the Pacific Oceanic Fishery Investigations, United States Fish and Wildlife Service, Honolulu. Sometime after the removal of these exotic elements the tank was pumped dry, painted, and restocked with Hawaiian experimental fish. On July 29, 1953, Messrs. Eugene Nakamura and John Randall, of the University of Hawaii, captured a living *Omobranchus* from the tank, and on September 26 of that year Randall took three more by draining the tank.

It was originally presumed that the four *Omobranchus* represented an indigenous Hawaiian form not previously taken because of some habitat peculiarity. Subsequent examination of collections from Palmyra Island



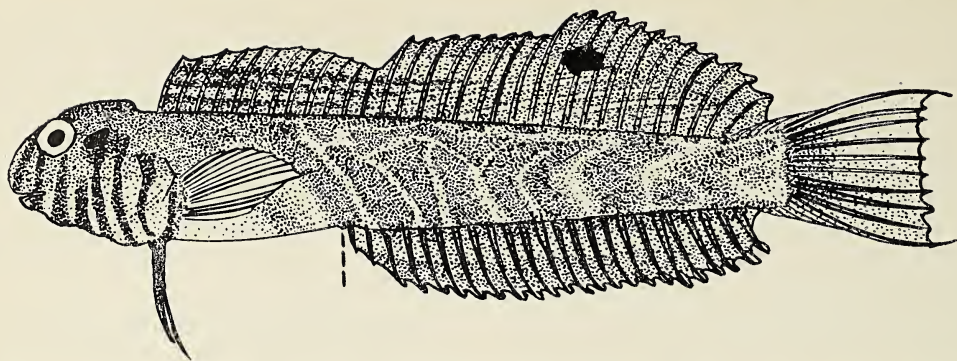


FIG. 3. *Omobranchus elongatus* (Peters), based on a mature male specimen from Coconut Island, Oahu. Scale represents 20 mm.

(a member of the Line group) showed a morphologically identical species to be present there, and it then appeared that perhaps the species was introduced into Hawaii when the *Tridacna* clams were brought to Coconut Island. If this is so, then it is difficult to explain how the fish withstood tank draining and painting. It is possible that they retreated a considerable distance into the inlet pipe, or that some had previously escaped, established a population in Kaneohe Bay, and then members of this population subsequently reentered the tank. That breeding populations have existed in Hawaii is evident from the size range of the four known specimens. The smallest of these is a gravid female measuring only 36 mm. in standard length; certainly this fish was hatched in Hawaii.

Regardless of the history and unorthodox locality record of *O. elongatus*, a strong possibility exists that it is now locally established in Hawaiian waters. The area where it is most likely to occur, Coconut Island and environs, has not been recently sampled because of the inadvisability of using rotenone near experimental ponds.

Counts and other distinguishing characters are given in Table 3 and the key, and the following color notes supplement Figure 3 as an aid in distinguishing this blenny.

*Color in life.* Body more or less translucent, vertebral column clearly visible in tail; ground color olive-brown becoming dull red below

midsides, belly grayish white; dorsal half of body covered with a reticulum of narrow white lines; on sides reticulum breaks up into a series of narrow parallel lines which slant posteriorly and ventrally. Ground color of head olive-green; opercle dull red-brown anteriorly and with an oval red-brown area posterodorsally; preopercle olive-green dorsally, breaking up into two or three green streaks separated by yellowish interspaces ventrally; head with dark vertical bars bordered by iridescent blue-green lines as follows: red-brown bar from front edge of eye to snout, olive-green bar across cheek and throat below center of eye, red-brown bar across cheek and throat at rear edge of eye, two red-brown bars across preopercle and throat, the second not meeting its opposite member, a short red-brown bar across branchiostegals from tip of preopercle to lower pectoral base. Membrane of spinous dorsal pinkish, broken into numerous lengthwise stripes with clear interspaces, spines yellowish with white tips; membrane of soft dorsal yellowish-hyaline with a few diagonal pinkish lines basally, rays yellowish, their tips iridescent blue-white, and a brilliant blue-green spot between rays 10 to 12; caudal fin membrane hyaline, caudal rays yellow; anal fin yellowish-hyaline basally, gray distally, each ray with a conspicuous blue-white tip; pectorals yellow-hyaline; ventrals orange-yellow; iris bronze, pupil black (based on a male

specimen 52 mm. in standard length).

The specimen from which the above notes were made was placed alive into 5 per cent formalin upon which it developed a color pattern suprisingly different from that of life. All white and blue-green lines disappeared from the head and body, the interspaces between them turning dark brown and forming the oblique and vertical bars noted in the key. An oval black spot also appeared on the head behind the eye. The reported variability in the presence or appearance of the body bars or the head spot is probably partially dependent on how soon after death specimens are preserved.

Three of the Hawaiian specimens are males and have a standard length range of from 52 to 56 mm. All have the spot on the soft dorsal noted above and by Peters (1855: 249), and in the most mature specimen there is also a low fleshy ridge down the midline of the head, and a decided tendency for the tips of the last eight anal rays to be compressed and broad when viewed from the side. The single 36 mm. female lacks the soft dorsal spot, the head ridge, and compressed tips of the anal rays. Five specimens of what appears to be the same species from Palmyra Island have a length range of only 33–46 mm., yet all are sexually mature. Here, too, females lack the soft dorsal spot of the males.

The ecology of *O. elongatus* is not well known except as noted above for the collection locale. The Palmyra specimens came from a shallow inshore reef. Distribution of the species includes East Africa, the East Indies, and the Central Pacific.

MATERIAL EXAMINED: 4 Oahu in writer's collection; 5 Palmyra at UH.

### Genus RUNULA Jordan and Bollman

*Runula* Jordan and Bollman (1890: 171). Type of genus, *Runula azalea* Jordan and Bollman.

Schultz's separation of *Runula* from *Aspidontus* (1950: 266) has been followed in this report.

### *Runula ewaensis* (Brock)

*Petrosirtes ewaensis* Brock (1948: 125, type locality, off Ewa Beach, Oahu).

*R. ewaensis* is apparently a moderately deep-water inhabitant, and has been taken only rarely to date. Of the five known specimens, two came from depths of about 120 feet and one, the holotype, from 30 feet. It is of interest that the holotype and one of the specimens from 120 feet were taken from pipes hauled to the surface. It is suggested that examination of the pipe frameworks of Hawaiian fish traps might yield additional specimens and perhaps throw some light on the biology of this blenny.

An attempt has been made to determine the systematic position of *ewaensis*, and the species appears to be most closely related to *R. rhinorhynchos* (Bleeker, 1852: 273) of the East Indies, Palau, etc. Meristic differences between the two may be summarized briefly as follows: *ewaensis* has 34 or 35 soft dorsal rays while *rhinorhynchos* has 32 or 33; *ewaensis* has 32 or 33 soft anal rays, and *rhinorhynchos* has 29 or 30. From the standpoint of color pattern, *rhinorhynchos* has two plain, lengthwise blue stripes against a brownish background (cf. Smith, 1950: pl. 21, fig. 962), while in *ewaensis* these stripes are edged in black and the ground color is pale (brick red in life). Three Philippine specimens of *rhinorhynchos* at USNM differ from Smith's figure in having a black blotch on each side of the caudal peduncle which extends about one-third to one-half the length of the caudal fin. This spot is usually lacking in *ewaensis*, but when present it ends at the flexure denoting the caudal fin base. The brick red ground color and two lengthwise blue stripes are sufficiently distinctive to make identification of specimens an easy matter.

*R. ewaensis* has been reported only from Oahu and is regarded as endemic to the Hawaiian Islands for the present. Its habitats cannot be considered well sampled, however,



and it is possible that the species will be taken elsewhere.

MATERIAL EXAMINED: *R. ewaensis*, holotype and 1 other Oahu at USNM; 1 Oahu in collections of Honolulu Aquarium; 2 Oahu in writer's collection.  
*R. rhinorbhynchos*, 3 Philippines at USNM.

**Runula goslinei**, new species  
Fig. 4

HOLOTYPE: USNM No. 164202, a female, 43 mm. in standard length, taken in a shallow-water rotenone station at Pupukea, Waimea coast, Oahu, T. H., on December 23, 1949, by Gosline, Strasburg, and party.

PARATYPES: USNM No. 164203, 1 specimen 38 mm. in standard length, taken with the holotype; USNM No. 164204, 1 specimen 37 mm. in standard length, taken in a shallow-water rotenone station at Makapuu Beach, Oahu, T. H., on October 2, 1952, by Gosline and party; USNM No. 108503, 1 specimen 38 mm. in standard length, caught on reef off Mokuleia, Waialua, Oahu, in 1937 by Otto Degener.

DESCRIPTION: Counts made on *R. goslinei* are recorded in Table 3, and detailed measurements, expressed in thousandths of the standard length, made on the holotype and two paratypes appear in Table 4.

Dorsal rays VIII, 34-37 (usually 35); anal II, 29 or 30, first anal spine minute and partially embedded in females; pectoral 12; pelvics I, 3, spine and mesial ray visible only

TABLE 3  
COUNTS MADE ON SPECIES OF *Runula* AND *Omobranchus*

		<i>R. goslinei</i>	<i>R. tapeinosoma</i>	<i>R. ringens</i>	<i>O. elongatus</i> (OAHU)	<i>O. elongatus</i> (PALMYRA)
Dorsal fin	VII	1				
	VIII	10	11	12		
	IX		1	1		
	X		1			
	XI					
	XII				4	5
	19				3	4
	20				1	1
	32			1		
	33			6		
Anal fin	34	1	1	6		
	35	6	4			
	36	1	8			
	37	1				
	II	9	13	13	4	5
	20				1	
	21				1	4
	22				2	1
	27			3		
	28			4		
Pectoral fin (both sides counted)	29	6	3	5		
	30	2	9	1		
	31		1			
	10		1			
	11					
Number of upper pectoral rays encompassed by gill openings (both sides counted)	12	16	15	23	8	10
	13			3		
	4					6
	5	9	6	10	4	4
	6	5		16	4	

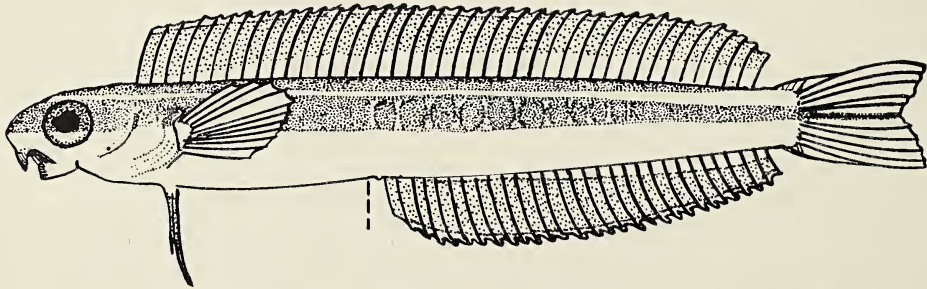


FIG. 4. Holotype of *Runula goslinei*, new species (USNM No. 164202) from Pupukea, Waimea Coast, Oahu. Scale represents 10 mm.

with staining and dissection; principal caudal rays 11, none branched; no nuchal, nasal, or supraorbital cirri; teeth incisiform, firmly attached, immovable, an enormous fang-like canine on dentary; incisiform teeth totaling 32–56 in lower jaw and 21–28 in upper, the number increasing with growth; gill opening a small slit running from above pectoral base to level of fifth or sixth ray from top of pectoral fin.

Head 4.0–4.5; greatest depth 6.9–7.9; longest dorsal spine 9.2–11.0; longest pectoral ray 7.3–8.2; all in the standard length; eye 3.2–3.8; snout 3.8–4.8; interorbital space 3.2–3.5; postorbital length of head 2.1; least depth of body 2.8–3.2; greatest depth of body 1.5–2.0; all in length of the head.

Dorsal fin entire, spinous part slightly lower than soft-rayed portion; last dorsal and anal rays membranously attached to caudal peduncle, attachment occurring anterior to small caudal rays; snout pointed; mouth subterminal, inferior; lips smooth; four tiny tentacles just posterior to lower lip in some specimens; lateral line absent (?); fifth or sixth pectoral ray from upper edge of fin longest, reaching posteriorly to level of second soft dorsal ray; caudal fin slightly forked.

*Color in alcohol.* Lower half of head and body silvery white, upper half brown, the two colors sharply separated at level of lower edge of pupil; a narrow white line down dorsal midline of head from near tip of snout to base of first dorsal spine; a second narrow white line from side of snout to dorsolateral portion of caudal peduncle, touching upper edge of eye and broadening beneath soft dorsal; second line divides brown portion of body into a narrow upper band and a broader lower one; upper band uniformly brown, lower band either uniform or with 10–18 pigment intensifications along its length so that band appears spotted; lower band narrow and without spots on caudal peduncle, and extends to rear edge of caudal fin as a streak covering middle caudal ray; upper band becomes narrow posteriorly and disappears be-

low last soft dorsal ray; upper surface of caudal peduncle whitish; entire ventral half of head and body silvery white, unmarked; dorsal fin hyaline for basal two-fifths, then a broad submarginal brown band, with distal edge of fin white; caudal fin white except for median brown streak and scattered brown pigment spots at tips of outermost rays; pectorals hyaline; pelvics white; basal fourth of anal fin hyaline, then a broad submarginal brown band, with distal edge of fin white; upper two-thirds of iris blackish, lower third silvery white. Some variability has been noted with respect to spotting along the lower lateral band. The dark pigment ranges from golden brown to brownish black, and pigment intensifications may be either lacking, poorly defined and not countable, or fairly distinct and numbering from 10 to 18.

*Color after twenty hours preservation in formalin.* (Based on holotype and one paratype.) Upper half of head and body brownish black, lower half white; line down midline of head and line separating dark area into lengthwise bands bluish green; area around mouth yellowish green (holotype), faintly yellow (paratype); dorsal and anal transparent, yellowish, with a broad submarginal brown band; caudal transparent, tinged with yellow, outer rays somewhat dusky, median ray brown and bordered with yellowish white; pectoral transparent, colorless; pelvics white.

*ECOLOGY:* Of the 11 known specimens of *R. goslinei* specific habitat data can be given for only 4. These were taken with rotenone at depths of 3–5 feet along rocky seashores where there was some sand bottom and where water circulation was good. Another specimen was taken from a reef near Mokuleia, Oahu, presumably at a similar depth. The six remaining specimens were recovered from the stomachs of large fish, five being from dolphins (*Coryphaena hippurus*) and one from a yellowfin tuna (*Neothunnus macropterus*). These large fish were caught by trolling near Moku Manu (Bird Island), Kaneohe Bay, Oahu, and their stomachs also contained deep-water



scorpaenids and Anthiinae (family Serranidae), the former being demersal. It is presumed that the ingested *Runula* came from near the bottom and probably from depths considerably greater than those sampled with rotenone. The writer has not seen *R. goslinei* alive, and can make no statements on its behavior.

RELATIONSHIP: *R. goslinei* was originally thought to represent a juvenile stage of *R. tapeinosoma* (Bleeker, 1857: 64) of the East Indies, Micronesia, and the southeast Pacific. It was also found to have striking similarities to *R. ringens* (Vaillant, 1894: 74) of the Pacific coasts of the Americas. A critical examination of all three indicated that *goslinei* was an intermediate between two extremes. On one hand was *tapeinosoma*, occurring up to about 1,800 miles from Hawaii, and on the other, *ringens*, separated from Hawaii by more than 2,500 miles of "East Pacific Barrier," with *goslinei* being a geographical and morphological intermediate. It seems very unlikely that there is gene interchange between these widely separated populations, and their morphological similarities are probably better ascribed to a common ancestry rather than interbreeding.

Table 3 presents meristic data for these three blennies, the discrepancies between numbers of specimens in various categories reflecting the damaged condition of those obtained from fish stomachs. The general tendency indicated in Table 3 is that *tapeinosoma* has the most soft fin rays, *ringens* the fewest, and *goslinei* is intermediate. With regard to size, *goslinei* is a small form, becoming sexually mature at standard lengths of 35–40 mm. and probably not growing much beyond that, while *tapeinosoma* and *ringens* appear to be larger, most specimens ranging from 35–65 mm. in standard length. Color pattern and other differences are summarized in the following key which can be used to separate the three species.

1a. Anal fin transparent, colorless; dorsal soft rays 32–34. . . . . ***ringens***

1b. Anal fin with a submarginal brown band. [dorsal soft rays 35–37 (rarely 34).

2a. Submarginal brown band on dorsal and anal fins narrow, about one-half to two-thirds as broad as basal clear part of fins; brown band on sides broken into 15–20 vertically elongate spots, band absent or faint between some spots; anal soft rays usually 30. . . . . ***tapeinosoma***

2b. Submarginal brown band on dorsal and anal fins broad, equal to or up to twice as broad as basal clear part of fins, sometimes clear area completely lacking; brown band on sides of nearly uniform intensity, if spots present they are poorly defined and connected by band; anal soft rays usually 29. . . . . ***goslinei***

Notes on the life coloration of *ringens* (as *R. albolinea*) are given by Herre (1936: 403).

DISTRIBUTION: Thus far, limited to the Hawaiian Islands.

REMARKS: Named *goslinei* in honor of Dr. William A. Gosline of the University of Hawaii.

MATERIAL EXAMINED: *R. goslinei*, holotype and paratypes at USNM; 6 Oahu from fish stomachs at UH; 1 Kauai at POFI.

*R. tapeinosoma*, 5 Marshall Is. at USNM; 3 Marshall Is. and 5 Gilbert Is. at UH.

*R. ringens*, 9 Mexico, 1 Costa Rica, 1 Colombia, 1 Ecuador, and 1 Galapagos at USNM.

#### FAUNAL AFFINITIES

The Hawaiian blennies belong to or are derived from the East Indian faunal group, and of the nine genera here considered, all but *Tripterygion*, *Entomacrodus*, and *Runula* are confined to the Indo-Pacific area. Both *Tripterygion* and *Entomacrodus* occur in the warmer parts of the Atlantic and Indo-Pacific while *Runula* appears to be basically Indo-Pacific but occurs also on the tropical Pacific Coasts of the New World. No genus found in Hawaii is restricted to the Hawaiian area.

On the specific level, about 60 per cent of the blennioid fishes reflect the well-known

endemic nature of the Hawaiian fauna. The distribution of 8 of the 13 species (*Tripterygion atriceps*, *Istiblennius zebra*, *Entomacrodus marmoratus*, *Cirripectus obscurus*, *C. lineopunctatus*, *Enchelyurus brunneolus*, *Runula ewaensis*, and *R. goslinei*) is limited to the Hawaiian chain, Johnston, and Midway islands. One blenny, *Istiblennius gibbifrons*, also occurs at Wake Island, the fish fauna of which is predominantly Marshallese, while two others, *Exallias brevis* and *Cirripectus variolosus*, are widespread throughout the Indo-Pacific. Of the remaining two, *Omobranchus elongatus* is wide-ranging in the Indo-Pacific but probably artificially introduced into Hawaii, while *Ecsenius hawaiiensis* is known only from the Hawaiian Islands but under rather peculiar circumstances.

A summary of the distribution of the closest relatives of the endemic Hawaiian blennioids is presented in Table 5. Although distributional pathways are not evident from this table the data tend to fall into several geographical categories, the location of which relates species affinities to the direction of flow of ocean currents. In the first group are

wide-ranging species such as *I. edentulus*, *E. epalzeocheilos*, and *R. tapeinosoma*; the second is composed of western Pacific and Indian Ocean forms (*E. bicolor* and *R. rhinorhynchos*); the third of central Pacific species (*T. hemimelas*, *Istiblennius* sp., and *C. quagga*); the fourth of species from the southeastern Pacific (*Cirripectus* sp. from Easter Island, *E. ater*); the fifth of a form from the extreme eastern Pacific (*R. ringens*), and the last of a species from Lord Howe Island (*C. alboapicalis*).

It seems likely that the clockwise current systems north of the Equator have carried some East Indian blennies to southern Japan, Hawaii, and tropical Pacific America, and that the North and South Equatorial Currents have distributed these forms, or their derivatives, to the Marshall and Caroline Islands and to Easter Island, Tahiti, and Samoa. Further distribution in the central Pacific could be effected by local currents or by "island hopping" in areas where atolls are closely spaced. Isolation and other factors acting on variously dispersed stocks has led to their divergence on the specific or infra-specific level.

TABLE 4  
MEASUREMENTS, EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH,  
MADE ON CERTAIN HAWAIIAN BLENIIDAE

	<i>Cirripectus lineopunctatus</i>			<i>Runula goslinei</i>		
	HOLOTYPE	PARATYPE	PARATYPE	HOLOTYPE	PARATYPE	PARATYPE
Standard length (mm.)	59.0	69.0	62.6	42.7	37.7	37.2
Head length	280	284	277	223	236	248
Greatest depth of body	280	316	247	145	130	126
Least depth of body	119	106	112	80	74	78
Postorbital length of head	186	194	190	105	111	118
Eye diameter	63	61	67	70	72	65
Snout length	92	97	85	47	53	65
Fleshy interorbital	34	30	32	68	74	70
Least distance between eye and nuchal fringe	115	115	115	...	...	...
Longest dorsal spine	278	184	307	91	109	100
Longest dorsal soft ray	186	197	200	96	122	108
Longest soft anal ray	142	130	136	91	111	108
Longest pectoral ray	203	219	195	127	122	137
Longest pelvic ray	149	145	133	122	159	156
Longest caudal ray	237	235	228	180	175	186
Snout tip to anus	508	528	493	429	419	437
Snout to dorsal origin	272	295	303	169	204	210
Length anal base	449	385	449	491	488	525
Sex	♂	♀	♂	♀	?	?



TABLE 5  
DISTRIBUTION OF CLOSEST RELATIVES OF ENDEMIC HAWAIIAN BLENNIES

HAWAIIAN SPECIES	CLOSEST RELATIVE	DISTRIBUTION OF CLOSEST RELATIVE
<i>Tripterygion atriceps</i> .....	<i>T. bemimelas</i>	Phoenix and Samoan Islands
<i>Istiblennius zebra</i> .....	<i>I. edentulus</i>	Entire Indo-Pacific
<i>Istiblennius gibbifrons</i> .....	<i>Istiblennius</i> sp.*	Marshall, Gilbert, and Phoenix Islands
<i>Entomacrodus marmoratus</i> .....	<i>E. epalzeocbeilos</i>	East Indies, India, Ceylon, Samoa
<i>Ecsenius hawaiiensis</i> .....	<i>E. bicolor</i>	East Indies, India, Burma, Red Sea, Formosa, New Hebrides, Caroline Islands
<i>Cirripectus obscurus</i> .....	<i>C. alboapicalis</i>	Lord Howe Island
	<i>Cirripectus</i> sp.	Easter Island
<i>Cirripectus lineopunctatus</i> .....	<i>C. quagga</i>	Marshall, Gilbert, Phoenix, and Wake Islands, Samoa
<i>Encbelyurus brunneolus</i> .....	<i>E. ater</i>	Tahiti, Samoa
<i>Runula ewaensis</i> .....	<i>R. rhinorhynchos</i>	East Indies, Philippines, East Africa, Caroline Islands
<i>Runula goslinei</i> .....	<i>R. tapeinosoma</i>	East Indies, East Africa, Caroline, Marshall, Society, and Samoan Islands
	<i>R. ringens</i>	Pacific coasts of Americas

\*To be described in the second volume of the "Bikini Reports" of Schultz *et al.*

The close similarity between species with great geographical separation, such as *E. brunneolus* and *E. ater*, or *R. goslinei*, *R. ringens*, and *R. tapeinosoma*, is explicable on these grounds, the major supposition being the ability of migrants to withstand a pelagic journey. Confirmative evidence for this ability is available from data derived from high-seas plankton collections made by POFI. Large blenny larvae are considerable components of some collections, and it is significant that the genus *Tripterygion* has been taken 285 miles from land in the vicinity of the Line Islands, and that *Aspidontus* (closely related to *Runula*) occurred about 110 miles from land in the same area. Specimens of *Istiblennius* and *Cirripectus* were found as much as 15 miles offshore, with other genera appearing closer inshore. The fact that these larvae were large (of sizes equal to or only slightly smaller than juveniles) suggests that their pelagic welfare had been good, and that an open sea life was normal.

It is difficult to explain the maintenance of Hawaiian endemism if the influx and egress of larvae occurs at the appreciable rate suggested by the number of specimens in plankton collections. The occurrence of *I. gibbifrons* at Wake Island may represent the beginnings of a breakdown in Hawaiian endemism, and

the single-specimen records of other species mentioned in the introduction may similarly represent stragglers from remote areas.

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## Pacific Ferns Described in Nightingale's *Oceanic Sketches*

FRANCIS BALLARD<sup>1</sup>

THIS PAPER has been written as a direct result of an enquiry by Professor Harold St. John of the University of Hawaii. The information obtained was felt to be of sufficient interest to present to a wider audience, especially as it involves the identity of certain species of ferns from the Southern Pacific described by W. J. Hooker in a little-known work on oceanic travel.

The book in question was written by Sir Thomas Nightingale, an English gentleman about whom little seems to have been recorded in the usual books of reference. A search made in the Hooker letters at Kew has failed to produce any correspondence between Nightingale and Hooker, and the Dictionary of National Biography is equally reticent.

However, *Oceanic Sketches* appeared in 1835, being an account of a journey extending over nearly two years to various islands in the South Pacific as well as to Chile and Peru. It is stated that the expedition was undertaken partly for scientific reasons and we know that the author made a collection of dried plants during his wanderings.

Appended to the narration of his travels is a six-page supplement written by Sir William Jackson Hooker, at that time Dr. Hooker, on the ferns, 29 species in all, collected by Night-

ingale. Of these, five were described as new; as the specimens appear never to have been critically examined, the following observations may be of interest.

Since *Oceanic Sketches* is a somewhat rare work, Hooker's descriptions and observations are reproduced verbatim as follows.

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12. *Aspidium* ? *Amoa*, n. sp. tota pubescens, frondibus pinnatis, pinnis alternis oblongis obtusiusculis sessilibus membranaceis ad apicem serrulatis, basi truncatis, sursum breviter auriculatis, soris . . .

Allied in general appearance, to *Asp. exaltatum* and *biserratum*, but the frond is all over downy, especially the stipes, rachis, and midrib. There is, unfortunately, no fructification on the specimens, which is, however, probably marginal. "Amoa" is marked as the native name of the plant.

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21. *Lindsaea propinqua*, n. sp.; fronde bipinnata, pinnis subquinque patentibus, pinnulis oblongo-trapeziformibus margine superiore crenato-lobatis, infimis cuneiformibus, soris fere exacte marginalibus interruptis.

The species most nearly allied to this is the West Indian *L. trapeziformis* of Dryander; but in that, the pinnules are entire, and the sori continuous. The *L. trapeziformis*, again, of Langsdorff and Fischer, (from Brazil) has the sori interrupted, as in our plant, but, at the same time, placed considerably within the almost entire margin of the pinnules.

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26. *Alsophila* ? *polypodioides*, n. sp.; fronde bipinnata, pinnulis oblongo-lanceolatis attenuatis sessilibus crenato-pinnatifidis, lobulis unisoriferis, rachibus valde pilosis, stipite aculeato.

This is probably, a tall-growing tree-fern, of which the fronds are considerably different from any species with which I am acquainted. The stipe is rather stout, rough, with very short prickles below. Primary pinnae almost opposite, 6–8 inches long, much attenuated at the apex, as are the secondary ones: these latter bear pinnules, which are quite sessile and adnate, but not decurrent, 6–8 lines long, tapering upwards, hairy in the younger parts, crenato-pinnatifid, the crenatures, or lobules, bearing a sorus, which occupies nearly the whole space between the margin and the centre, and is totally destitute of involucre, but evidently inserted at the forking of a nerve. The rachis is every where clothed with rather long patent hairs, some of which are chaffy. The narrow pinnules, singularly incurved at the margins, and long attenuated extremities, are very characteristic of this species.

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27. *Trichomanes glauco-fuscum*, n. sp.; fronde subovata bipinnatifida, laciniis linearibus bi-trifidis obtusiusculis, marginibus integerrimis pallidioribus, involucris paullo ante apicem laciniarum brevium insertis cylindraceis, ore integerimo dilatato, stipite elongato gracili.

The fronds are ovate, 2–3 inches long, twice shorter than the slender stipes, and remarkable, in the dry state, for a brown colour tinged with a grayish bloom, and if the plant be held between the eye and the light, the margin will be seen to be paler than the centre of the lacinae.

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29. *Hymenophyllum polyanthum*, n. sp.; alatum, rigidum, fronde lanceolata pinnata, pinnis profunde bipinnatifidis, laciniis attenuatis integerrimis obtusis, involucris copiosis axillaribus lato-urceolatis nitidis, ore valde membranaceo dilatato obtuse bilabiato, stipite rachique (superne alata excepta) setosis.

This is certainly one of the finest species of this beautiful genus; a foot and a half long, stout and rigid, opaque, of a dark,

almost blackish green colour; the upper half abundantly furnished with axillary, conspicuous, glossy, very membranaceous involucres.

I have been able to find the type specimens of the five novelties in the Kew collections without much difficulty. They are here considered in order.

*Aspidium* ? *amoa* Hook.

The specimens were collected in Tahiti and the sheet is written up in Hooker's own hand. It is quite obviously a sterile specimen of a *Nephrolepis*, the largest frond being 23 cm. long and 5 cm. wide. It has the appearance of a young sporeling with herbaceous translucent fronds. Although the plant is described as "tota pubescens," it has only a sparse development of narrow, reddish brown hair-like scales on the rachis and the pinnae are almost glabrous. It may possibly be *Nephrolepis hirsutula* (Forst.) Pr. or even *N. exaltata* (L.) Schott *sens. lat.*

*Lindsaea propinqua* Hook.

The specimen, collected in Samoa, consists of two fronds, one sterile, one fertile, but no rhizome. It is figured in Hook., Sp. Fil. 1. 223 (1846) t. LXVI. B., the drawing being almost photographic in its accuracy.

The pinnae, 5 or 7, are from 4 to 4.5 cm. wide and are imparipinnate; they do not perceptibly taper upwards. There are from 7 to 13 pairs of pinnules per pinna.

C. Christensen in his Index Filicum reduced the species to "*L. decomposita* Willd. var." This species is usually regarded as an aggregate, and C. Christensen in his revision of the Pteridophyta of Samoa (1943) recognised three forms in Samoa. *Lindsaea propinqua* Hook., however, does not fit any of these. All three agree in possessing linear-lanceolate pinnae with 20 or more pinnules which taper gradually upwards. They are 2–3 cm. (rarely more) wide.

In the circumstances, it would seem wiser at present to retain *L. propinqua* Hook. as a distinct species.



*Alsophila* ? *polypodioides* Hook.

There are two sheets of this. One bears the words "S. Sea Islands" in addition to the name; the other, just "Society Islands."

Both are *Thelypteris leucolepis* (Pr.) Ching (*Dryopteris leucolepis* [Pr.] Max.) and not *D. ornata* (Wall.) C. Chr. as stated in C. Chr., Ind. Fil.

*Trichomanes glaucofuscum* Hook.

On a sheet of mixed collections there are two small fronds corresponding to Hooker's description and a caption above it in Hooker's writing, "Pacific Isles, Nightingale." The specimens are obviously *T. pallidum* Bl.

*Hymenophyllum polyanthum* Hook.

This species was figured as *Trichomanes polyanthum* Hook. in Hook., Ic. Pl. t. 703 from Nightingale's specimen. The locality given is "Pacific Isles" and Copeland (*in litt.*) has suggested Huahine, though this presumably is guesswork. The original sketches for t. 703 are drawn by Hooker on the sheet. Copeland regards the species, under *Trichomanes*, as distinct.

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## A Revision of the Pediculate Fishes of the Genus *Malthopsis* Found in the Waters of Japan (Family Ogcocephalidae)

AKIRA OCHIAI and FUMIO MITANI<sup>1</sup>

FISHES of the genus *Malthopsis* are for the most part rarely caught and little known. Since the genus was erected by Alcock in 1891 for the accommodation of *Malthopsis luteus*, about twelve species have been described by several authors from the Indo-Pacific region. From Japanese waters, Jordan (1902: 378-379) described a new species, *Malthopsis tiarella*, based on a specimen taken from Suruga Bay, when he revised the pediculate fishes or anglers of Japan. Then, Tanaka reported two new species, *Malthopsis annulifera* (1908: 44) and *Malthopsis kobayashii* (1916: 348) from the Bay of Sagami and Ise (?), respectively. Subsequently, the occurrence of *Malthopsis mitrigeria* Gilbert and Cramer and *Malthopsis lutea* Alcock were reported by Kamohara (1936a: 22; 1936b: 935) on the basis of specimens obtained from Tosa.

The classification of the group, which has been based on rather unstable morphological features of these fishes, is still far from being satisfactorily understood. For instance, *M. annulifera* and *M. kobayashii* have been synonymized with *M. tiarella* by Tanaka (1931: 43) and also by Kamohara (1934a: 194-195; 1934b: 1202); further, *M. mitrigeria*, *M. tiarella*, *M. annulifera*, and *M. kobayashii* have been united with *M. lutea* by Kamohara (1937a: 13; 1937b: 119-121). On the other hand,

Okada and Matsubara (1938: 458-459), although agreeing in general with Kamohara's treatment, have separated *M. mitrigeria* from *M. lutea*. Recently, Kamohara (1950: 277-278; 1952: 103-104) altered his previous view and distinguished the four species based on the general form of the subopercular spine and the number of dorsal fin rays.

Lately the present authors have examined a rather large number of specimens, which are referable to the genus *Malthopsis*, taken by deep-sea trawlers off the Pacific coast of Japan at a depth of about 100 fathoms and deposited in the Department of Fisheries, Faculty of Agriculture, Kyoto University. We have finally come to the conclusion that they represent five distinct species, *M. mitrigeria*; *M. annulifera*, *M. lutea*, *M. tiarella*, and *M. jordani* Gilbert, the last of which has never been obtained from Japanese waters.

In this paper, the body length is indicated by a measurement from the tip of the lower jaw to the base of the caudal fin; the disk length is measured from the tip of the lower jaw to the vent; the greatest breadth of the disk is recorded as a distance between the outermost points of the most prominent subopercular spines; the tail width is measured at the beginning of the anal fin; and the rostral spine length is the distance from its tip to a line drawn across the anterolateral sides of the disk as in Figure 1. In order to determine the size of the dark ring-like mark-

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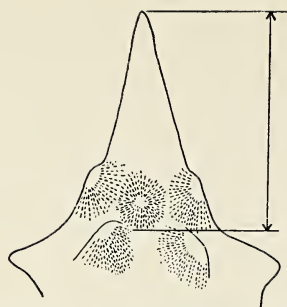


FIG. 1. Diagram showing the measurement used as the length of the rostral spine.

ings, the area of a marking at the right side of the disk and nearest to its midline, is calculated by the planimeter. Teeth are cleared in potassium hydroxide and stained with alizarine red.

We wish to express our sincere gratitude to Professor Kiyomatsu Matsubara for his kind supervision during the course of this study. We are also greatly indebted to Dr. Yaichiro Okada and Mr. Kiyoshi Suzuki for their kindness in sending us several valuable specimens taken from the Kumano Nada. The expenses for executing the studies of the present series were defrayed from the research fund of Kyoto University by Keizo Shibusawa from 1943 to 1945 and by the Ministry of Education from 1950 to 1953.

SYSTEMATIC SIGNIFICANCE OF VARIOUS BODY CHARACTERS

FIN RAYS: The rays in the dorsal and pectoral fins differ in number in certain cases, and are of some importance in the classification of the species of *Malthopsis* (Table 1).

The counts of dorsal rays are generally 5 in *M. mitrigeria*, *M. annulifera*, and *M. lutea* and 6 in *M. jordani* and *M. tiarella* (in holotypes of *M. jordani* and *M. tiarella* this count is 6 and 7, respectively). The count of pectoral rays is 11–13 and usually 12 in *M. annulifera*, *M. lutea*, and *M. tiarella*, but the count is generally 13 in *M. jordani* and 13–15 in *M. mitrigeria*.

MARKINGS: Color markings on the upper surface of the disk are valuable in distinguishing some of the species of *Malthopsis* (Table 2). There are no discernible markings in specimens of *M. mitrigeria*. Irregular blackish brown specks are found in *M. tiarella*. About half of our specimens of *M. jordani* and *M. lutea* are unmarked, while the others in each of these species are provided with blackish ring-like markings on each side of the median line of the disk. In the specimens of *M. annulifera*, 5–12 ring-like markings are present on the dorsal surface of the disk. The intra-specific variability of the size of ring-like markings is rather prominent, but it is evident from Figure 2 that the relative size of marking at a given standard length is largest in the specimens of *M. lutea*. The markings are larger in *M. annulifera* than in *M. jordani*.

DERMAL OSSICLES: The surface of the body is completely covered with dermal ossicles. Some of these are enlarged and tubercular in shape and are herein called bony tubercles. In this paper we have taken up the arrangement of bony tubercles on the dorsomedian portion of the disk. A row of the tubercles set on the median line of the upper surface of the disk is the so-called median row. Rows

TABLE 1  
DORSAL AND PECTORAL FIN RAY COUNTS IN FIVE SPECIES OF MALTHOPSIS FROM JAPAN

SPECIES	DORSAL FIN RAYS			TOTAL	PECTORAL FIN RAYS					TOTAL
	4	5	6		11	12	13	14	15	
<i>M. mitrigeria</i> .....	1	5	..	6	..	..	2	3	1	6
<i>M. jordani</i> .....	..	3	4	7	..	1	5	1	..	7
<i>M. annulifera</i> .....	2	23	..	25	1	19	6	..	..	26
<i>M. lutea</i> .....	..	32	2	34	4	30	..	..	..	34
<i>M. tiarella</i> .....	..	..	2	2	..	2	..	..	..	2

of the tubercles running backward from the postorbital rim to a tubercle of the median row are named mediolateral rows. The number and size of the tubercles of these rows, and the point of junction of the median row and the mediolateral rows, are the most valuable characters in the taxonomy of this group.

Particular attention, hitherto, has not been paid to the dermal ossicles on the ventral surface of the disk, but we have found that the mode of their arrangement and their relative size are useful for the classification of this group, though such features are somewhat unstable.

SUBOPERCULAR SPINE: Attention is drawn to the direction of protrusion of the subopercular spine and the number and direction of the prominent spinules at the tip.

CIRRI: So far as descriptions and figures of the fishes of this group are concerned, the dermal cirri which are present on the outer sides of the body have never been noted by any researchers. We have carefully observed material in the water, and consequently we have found that some of the specimens in *M. annulifera* and *M. lutea* are provided with very feeble cirri on the outer side of the body. We cannot tell for certain whether or not the other three species of this group have the cirri, for they are very feebly developed and might be torn off at the time of preservation.

SIZE: Absolute size of the body is an important taxonomic feature. *M. jordani* is the largest form in this group, reaching 140 mm. in total length, and even the smallest specimen we have observed is nearly 100 mm. in

entire length. *M. mitrigeria*, *M. lutea*, and *M. tiarella* are much smaller and even the largest specimen is not more than 100 mm. On the other hand, *M. annulifera* is moderately large and attains a total length of 118.5 mm., based on our observations.

DISTRIBUTION: The fishes of this group, in general, are rather rare in Japan. Although they are very frequently taken by motor trawlers on the Pacific coast of middle and southern Japan, they have never been obtained from either northern Japan or the Sea of Japan. Of the species, *M. annulifera* and *M. lutea* are commoner than the others. It is assumed that these two species may presumably be living in similar ecological conditions, because in many cases they are obtained together. *M. jordani* and *M. mitrigeria*

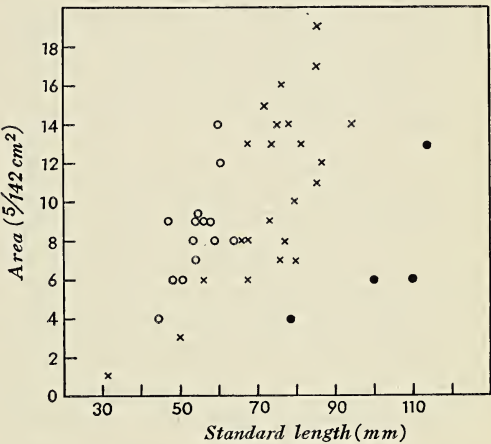


FIG. 2. Relation between standard length and the size of ring-like marking in three species of *Malthopsis*. ○, *M. lutea*; ×, *M. annulifera*; ●, *M. jordani*.

TABLE 2  
FREQUENCY DISTRIBUTION OF THE NUMBER OF RING-LIKE MARKINGS ON THE DORSAL SURFACE OF THE DISK IN FOUR SPECIES OF MALTHOPSIS

SPECIES	NUMBER OF MARKINGS PRESENT												
	0	1	2	3	4	5	6	7	8	9	10	11	12
<i>M. mitrigeria</i> ..	7	..	..	..	..	..	..	..	..	..	..	..	..
<i>M. jordani</i> ...	3	..	2	..	1	1	..	..	..	..	..	..	..
<i>M. annulifera</i> ..	..	..	..	..	..	3	7	8	4	2	..	..	2
<i>M. lutea</i> .....	16	..	5	1	3	..	3	1	3	..	..	..	..



are rare, although specimens of these species are frequently obtained with those of *M. annulifera* and *M. lutea*. *M. tiarella* is very rare and we have been favored with only two specimens taken from off Owasi and Kôchi. The specimens of this group taken off Owasi on January 19, 1937, by K. Matsubara contained four different species but not *M. annulifera*.

TAXONOMY

KEY TO THE SPECIES OF *Malthopsis*

- 1a. Subopercular spine greatly produced laterally, bearing 4 obvious spinules, 2 of them directed forward and 2 backward; ventral surface of disk covered with radially striated bony tubercles as large as those of dorsal surface; band of vomerine teeth elongated transversely, rectangular; peritoneum dusky; tail very slender, the width usually more than 10.0 in standard length; dorsal surface of disk without markings . . . . . **mitrigeria**
- 1b. Subopercular spine neither greatly protruding outward nor ending in 4 obvious spinules, antrorse spinule either single or wanting; ventral surface of disk covered with minute tubercles; the patch of vomerine teeth rather quadrangular; peritoneum pale; tail moderately thick, the width usually less than 10.0 in standard length; dorsal surface of disk with or without markings . . . . . 2
- 2a. Subopercular spine directed outward with a projecting antrorse spinule at the tip; ventral surface of disk sparsely covered with rather small bony tubercles . . . . . 3
- 2b. Subopercular spine directed outward and backward, forming a triangular process, without a projecting antrorse spinule at the tip; ventral surface of disk thickly covered with minute bony prickles . . . . 4
- 3a. Bony tubercles on dorsal surface of disk pointed and but slightly granulated, forming 3 rows on forehead; mediolateral rows of tubercles joined to median row

- at posterior portion of disk; bony tubercles lying between vent and pelvic fins continuous . . . . . **jordani**
- 3b. Bony tubercles on dorsal surface of disk rather pointed and noticeably granulated, forming 2 rows on forehead; mediolateral rows joined to median row at anterior portion of disk; bony tubercles lying between vent and pelvic fin few, scattered . . . . . **annulifera**
- 4a. Bony tubercles on dorsomedial surface forming 3 or more rows on forehead; dorsal surface of disk with or without ring-like markings; dorsal rays usually 5 . . . . . **lutea**
- 4b. Bony tubercles on dorsomedial surface forming 2 rows on forehead; dorsal surface of disk without ring-like markings, but with scattered blackish brown specks; dorsal rays 6 or 7 . . . . . **tiarella**

**Malthopsis mitrigeria** Gilbert and Cramer  
Kagi-furû-uo ( Japanese name)  
Figs. 3, 4

*Malthopsis mitrigeria* Gilbert and Cramer, 1896: 434-435, pl. 48, figs. 1-2; Jordan and Evermann, 1905: 524-525, fig. 229; Gilbert, 1905: 695; Fowler, 1934: 450; Kamohara, 1936a: 22; Okada and Matsubara, 1938: 458; Kamohara, 1950: 287; Kamohara, 1952: 103.

*Malthopsis triangularis* Lloyd, 1909: 169, pl. 45, figs. 1-1a; Barnard, 1927: 1009; Smith, 1949: 427, fig. 1227.

*Malthopsis lutea* (partim) Kamohara, 1937a: 13, pl. 2, fig. 5.

MATERIAL EXAMINED: Nos. 4156, 4157, 4162, 4165, 4930, and 4932 (the numbers refer to Matsubara's Fish Collection), 29.0-61.0 mm. in standard length (32.0-74.0 mm. in total length), off Owasi, Mie Pref., January 19, 1937; No. 15169, 73.0 mm. (86.5 mm.) off Owasi, January 18-20, 1950.

D. 4-5; A. 4; C. 9; P. 13-15; V. 1, 5. Disk length 1.79-1.98 (1.85) in standard length; disk width 1.04-1.26 (1.12); tail width 10.20-

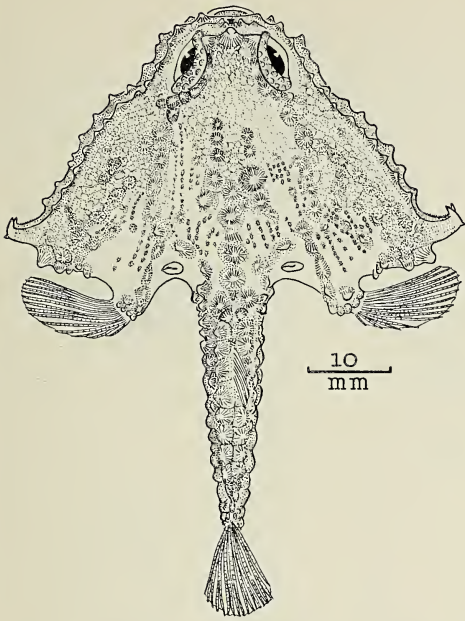


FIG. 3. Dorsal aspect of *Malthopsis mitrigeria* (specimen no. 4157, 58.0 mm. in standard length).

13.22 (11.15). Disk width 0.55–0.71 (0.61) in disk length; eye diameter 3.37–4.60 (4.05); interorbital width 4.25–6.30 (5.21); rostral spine 8.40–10.80 (9.51); mouth width 2.84–3.72 (3.47); pectoral fin 1.98–2.60 (2.32); pelvic fin 2.31–3.54 (2.70).

Disk very broad, the greatest width slightly less than the length of body. Tail slender and short. Rostral spine nearly vertical or directed somewhat obliquely upward, the length nearly equal to or less than half the diameter of eye.

Dorsal surface of disk thickly covered with many dermal ossicles except for both opercular and shoulder regions; some of them enlarged and quite regular in their arrangement; radial striations of bony tubercles minute, smooth, but finely serrate when viewed through a lens (Fig. 4c); mediolateral rows each represented by 2 or 3 rather prominent tubercles; median row of tubercles beginning at the middle part of disk, leaving therefore a rather smooth space along the median line of forehead; each side of the first tubercle on median row armed with 1 or 2 noticeable

tubercles. Three rows of tubercles running along the anterolateral margin of disk, the upper row beginning at the posterodorsal part of upper jaw and bending slightly upward at the under side of posterior rim of orbit. Bony tubercles on ventral surface enlarged and in contact with each other; vent in center of a naked area of skin, surrounded by an elliptical basin with several tubercles; a double row of tubercles runs from base of pectoral fin to base of pelvic fin; an enlarged tubercle in front of pectoral fin, surrounded by several smaller ones; small dermal ossicles, moreover, scattered irregularly on thoracic region (Fig. 4A<sub>1</sub>, A<sub>2</sub>). Rest of ventral surface of disk naked. Tail completely surrounded with large bony tubercles.

Subopercular spine flattish, strongly protruding, bearing 4 obvious spinules at the tip, 2 of these distinctly directed forward, the other ones variable in size but smaller and directed outward and backward (Fig. 4B<sub>2</sub>); in young specimens, however, the spine is not so strongly protruded as in adults (Fig. 4B<sub>1</sub>).

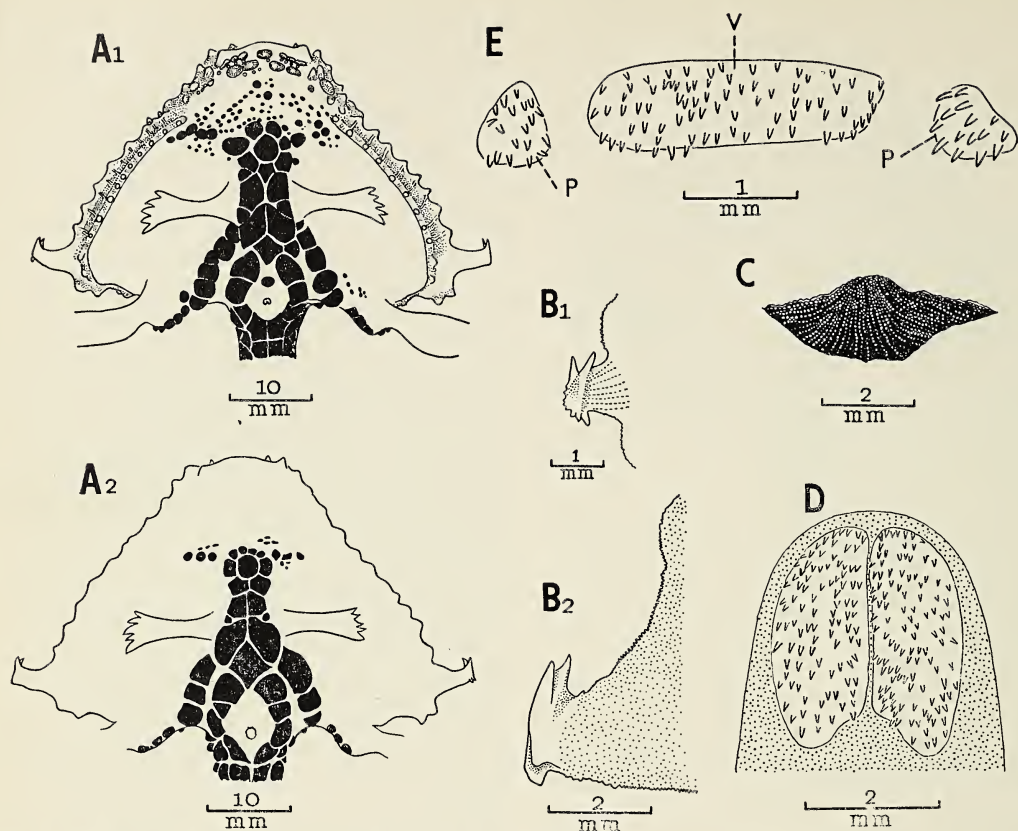
Sides of body without dermal cirri. Longest anal ray usually not reaching to base of caudal when the fin is laid back.

Band of vomerine teeth elongated laterally in form of rectangle (Fig. 4E); patch of teeth on palatine rather small and circular (Fig. 4E); teeth on tongue in 2 broad parallel bands, their posterolateral regions not divergent (Fig. 4D).

Color, in formalin, uniformly yellowish brown above, without any markings; pale below; fins also pale; peritoneum dusky.

REMARKS: Our specimens thus far examined agree well with the original description of this species given by Gilbert and Cramer (1896: 434–435, pl. 48, figs. 1–2), except for the more numerous branchiostegal rays (5 instead of 4) and somewhat shorter tail. *Malthopsis triangularis* Lloyd (1909: 169, pl. 45, figs. 1–1a) should be included in the synonymy of this species inasmuch as there is no obvious difference which will enable us to distinguish





[FIG. 4. *M. mitrigeria*: A<sub>1</sub>, ventral aspect of disk; A<sub>2</sub>, bony tubercles on ventral surface of disk; B<sub>1,2</sub>, subopercular spine of young and mature specimens; C, lateral aspect of bony tubercle in median line of dorsal surface of disk; D, dorsal surface of anterior part of tongue; E, teeth on vomer (v) and palatine (p). A<sub>1</sub> drawn from a specimen, 58.0 mm. in standard length (specimen no. 4157); A<sub>2</sub>, from a specimen, 55.0 mm. in standard length (specimen no. 4930); B<sub>1</sub>, from a specimen, 29.0 mm. in standard length (specimen no. 4932); B<sub>2</sub>, C, D, and E, from a specimen 61.0 mm. in standard length (specimen no. 4162).

it. Of the specimens belonging to Lloyd's types (1909: 175-176, pl. 48-49), W (with the arrangement of the dermal armature on body orderly and the disk width medium), X (with the dermal armature orderly and the disk narrow), and Z (with the dermal armature orderly and the disk broad) are all identical with this species.

#### *Malthopsis jordani* Gilbert

Kowanuke-furyu-uo (new Japanese name)

Figs. 5, 6

*Malthopsis jordani* Gilbert, 1905: 695-696, pl. 100; Jordan and Seale, 1906: 438; Böhlke, 1953: 148.

*Malthopsis lutea* (partim) Kamohara, 1937a: 13, pl. 2, fig. 4.

MATERIAL EXAMINED: No. 1629, 101.0 mm. (125.0 mm.), off Owasi, Mie Pref., December 6-9, 1935. Nos. 4152 and 4154, 88.5-113.5 mm. (112.0-140.0 mm.), off Owasi, January 19, 1937. No. 6798, 86.5 mm. (108.5 mm.), off Heta, Shizuoka Pref., November 22-24, 1938. No. 19062, 78.5 mm. (98.0 mm.), off Owasi, November 12-17, 1952. Nos. 20513 and 20514, 100.0-110.0 mm. (121.5-135.0 mm.), off Miya, Aichi Pref., April 8, 1953.

D. 5-6; C. 8-9; P. 12-14; V. 1, 5. Disk length 1.65-1.79 (1.71) in standard length; disk width 1.29-1.45 (1.37); tail width 7.69-

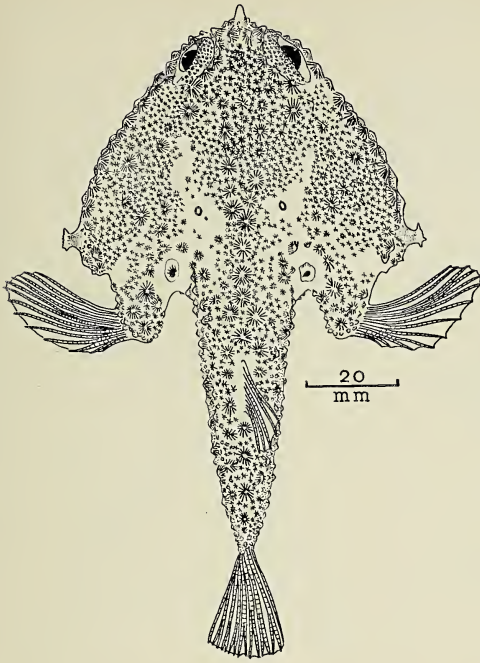


FIG. 5. Dorsal aspect of *Malibopsis jordani* (specimen no. 20513, 110 mm. in standard length).

8.63 (7.99). Disk width 0.77–0.82 (0.80) in disk length; eye diameter 4.28–5.95 (5.03); interorbital width 6.20–8.21 (7.09); rostral spine 8.91–13.70 (10.24); mouth width 3.68–4.46 (4.03); pectoral fin 2.30–3.12 (2.66); pelvic fin 2.46–3.12 (2.66).

Disk broad, the greatest width somewhat less than length of body. Tail rather slender and short. Rostral spine directed forward or forward and slightly upward, nearly half as long as diameter of eye.

Dorsal surface of disk rather thickly covered with dermal ossicles except for both opercular and shoulder regions; some of them enlarged, pointed and quite regular in their arrangement, radial striations of bony tubercles prominent, rather smooth but slightly granulated (Fig. 6C); mediolateral rows each represented by several tubercles, joined to median row of tubercles at posterior portion of disk; median row of tubercles developed throughout the entire length of disk, but the tubercles between those of the mediolateral

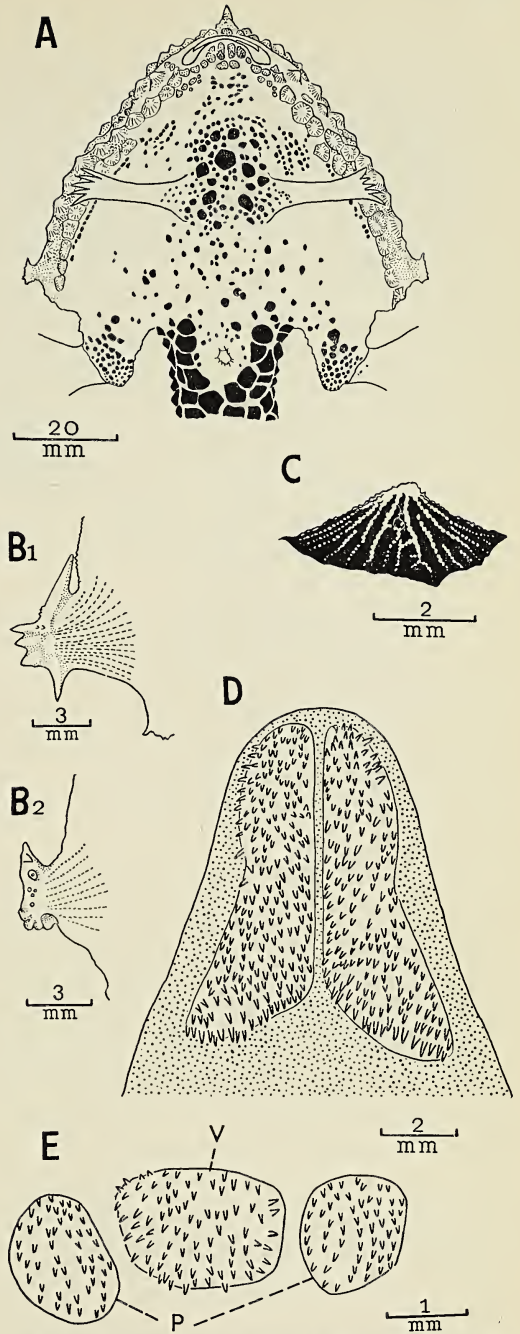


FIG. 6. *M. jordani*: A, ventral aspect of disk; B<sub>1,2</sub>, subopercular spine; C, lateral aspect of tubercle in median line of upper surface of disk; dorsal surface of anterior part of tongue; E, teeth on vomer (V) and palatine (P). A, from a specimen, 110.0 mm. in standard length (specimen no. 20513); B<sub>1</sub>, from a specimen, 78.5 mm. in standard length (specimen no. 19062); B<sub>2</sub>, from a specimen, 110.0 mm. in standard length (specimen no. 20514); C, D, and E, from a specimen, 86.5 mm. in standard length (specimen no. 6798).



rows scarcely enlarged. Three rows of tubercles running along the anterolateral margin of disk, the upper beginning at the posterior part of upper jaw, and turning sharply upward at the under side of posterior rim of orbit. Ventral surface of opercular region largely smooth, but the other parts with scattered tubercles which are flatter and smaller than those of dorsal surface; several tubercles between pelvics enlarged; small tubercles, moreover, scattered from thoracic to posterior edge of disk (Fig. 6A). Tail completely surrounded with large or small tubercles.

Subopercular spine short, protruding; the tip armed with projecting spinules, one of them prominent, directed forward (Fig. 6B<sub>1</sub>, B<sub>2</sub>).

Sides of body without dermal cirri. Longest anal ray reaching to or beyond the base of caudal when the fin is laid back.

Patches of vomerine and palatine teeth rather large, circular or quadrangular (Fig. 6E); teeth on tongue in two broad parallel bands, their posterolateral regions widely divergent (Fig. 6D).

Color, in formalin, yellow above, with or without black ring-like markings (of 7 specimens examined, 4 had 2 or 5 rings, the other 3 had none). Dermal ossicles on back brownish along their base and striations; ventral surface of body pale; a dark band crossing near the end of caudal; pectoral and dorsal dusky; pelvic and anal pale; peritoneum also pale.

***Malthopsis annulifera* Tanaka**  
 Wanuke-furyu-uo (Japanese name)  
 Figs. 7, 8

*Malthopsis annulifera* Tanaka, 1908: 44, pl. 1;  
 Jordan, Tanaka and Snyder, 1913: 428;  
 Kamohara, 1950: 287, fig. 220; Katayama,  
 1950: 12; Kamohara, 1952: 103–104, fig.  
 100.

*Malthopsis ocellata* Smith and Radcliffe in  
 Radcliffe, 1912: 207–208, pl. 18, fig. 1, pl.  
 19, fig. 1.

*Malthopsis tiarella* (*partim*) Kamohara, 1934a:  
 194–195, figs. 2–3.

MATERIAL EXAMINED: Nos. 1630–1632, 1634 and 1638, 50.0–81.5 mm. (63.0–101.0 mm.), off Owasi, Mie Pref., December 6–9, 1935. No. 2031, 31.5 mm. (40.5 mm.), off Owasi, April 13, 1936. Nos. 4134–4135, 4158 and 4295, 66.0–76.0 mm. (83.5–93.0 mm.), off Owasi, January, 1939. No. 4680, 56.0 mm. (69.5 mm.), off Owasi, December 1936. No. 4916, 94.5 mm. (118.5 mm.), off Owasi, February 3, 1938. No. 15171, 67.5 mm. (84.5 mm.), off Owasi, January 18–20, 1950. No. 17637, 77.0 mm. (95.5 mm.), off Miya, Aichi Pref., March 15, 1952. Nos. 19063–19064 and 19202, 73.0–85.5 mm. (93.5–108.0 mm.), off Owasi, November 12–17, 1952. Nos. 19675 and 19676, 75.0–85.0 mm. (94.0–104.0 mm.), off Nobeoka, Miyazaki Pref., December 10, 1952. Nos. 20515 and 20516, 72.0–76.0 mm. (91.5–93.0 mm.), off Miya, April 8, 1953. No. 20821, 80.0 mm. (101.0 mm.), locality and date unknown. Nos. 21072–21073, 82.0–

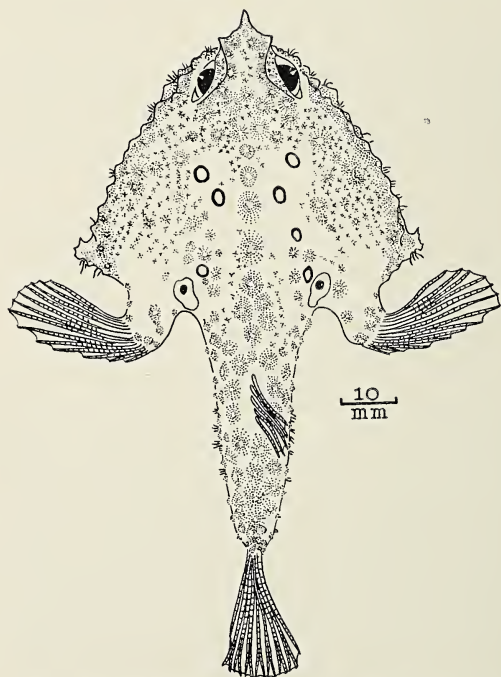


FIG. 7. Dorsal aspect of *Malthopsis annulifera* (specimen no. 19063, 85.5 mm. in standard length).

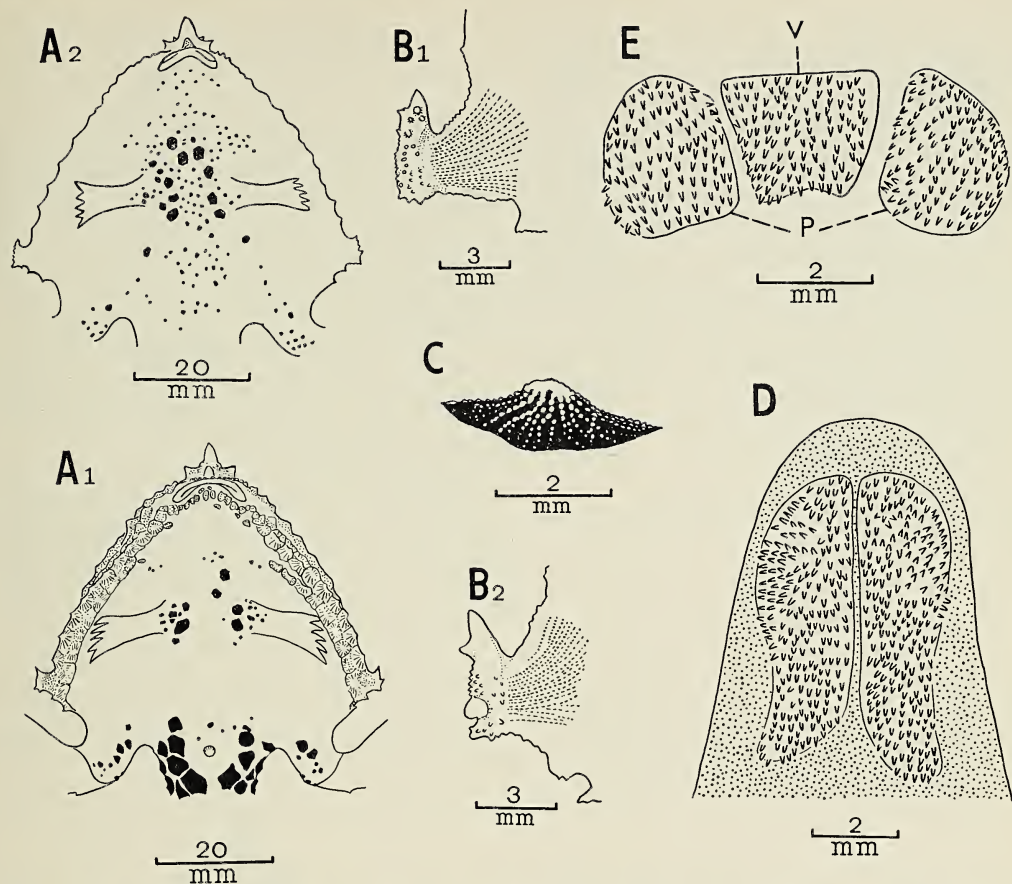


FIG. 8. *M. annulifera*: A<sub>1</sub>, ventral aspect of disk; A<sub>2</sub>, bony tubercles on ventral surface of disk; B<sub>1,2</sub>, subopercular spine; C, lateral aspect of bony tubercle in median line of dorsal surface of disk; D, dorsal surface of anterior part of tongue; E, teeth on vomer (V) and palatine (P). A<sub>1</sub>, from a specimen 85.5 mm. in standard length (specimen no. 19063); A<sub>2</sub>, from a specimen, 72.0 mm. (specimen no. 20515); B<sub>1</sub>, from a specimen, 77.0 mm. in standard length (specimen no. 17637); B<sub>2</sub>, from a specimen, 75.0 mm. (specimen no. 9675); C, D, and E, from a specimen, 79.5 mm. (specimen no. 1630).

90.5 mm. (104.0–112.0 mm.), off Owasi, November 5, 1953.

No. 1993 (the number refers to Mie University Fish Collection) 85.0 mm. (105.5 mm.), off Owasi, September 21, 1950. No. 4421, 87.0 mm. (107.0 mm.), off Owasi, February 1952.

D. 4–5; A. 4; C. 8–9; P. 11–13; V. 1, 5. Disk length 1.73–1.98 (1.88) in standard length; disk width 1.05–1.47 (1.29); tail width 6.66–8.23 (7.37). Disk width 0.58–0.76 (0.68) in disk length; eye diameter 3.81–5.46 (4.86); interorbital width 6.00–8.72 (7.28); rostral spine 5.69–14.83 (9.66); mouth width

3.31–4.54 (3.94); pectoral fin 2.26–3.11 (2.74); pelvic fin 2.57–3.33 (3.05).

Disk broad, the greatest width somewhat less than length of body. Tail rather slender and short. Rostral spine about half as long as diameter of eye, directed forward or slightly upward.

Dorsal surface of disk covered with dermal ossicles except for both opercular and shoulder regions; some ossicles enlarged, moderately pointed, and quite regular in their arrangement; radial striations of bony tubercles prominent, and noticeably granulate (Fig. 8C); mediolateral rows represented by



two rather large tubercles, and joined to median row at anterior portion of disk; median row usually ending behind orbits, leaving a smooth space between orbits; three rows of tubercles running along the anterolateral margin of disk, the upper row turning sharply upward ventral of posterior rim of orbit. Ventral surface largely smooth, but sometimes armed with many ossicles between pelvic fins as in *M. jordani*, some of them enlarged, the tubercles, however, generally flattish and much smaller than those of the dorsal surface (Fig. 8A<sub>1</sub>, A<sub>2</sub>). Tail rather sparsely surrounded with large bony tubercles.

Subopercular spine protruding, with a prominent antrorse spinule (Fig. 8B<sub>1</sub>, B<sub>2</sub>).

Sides of body with many dermal cirri. Longest anal ray usually does not reach to base of caudal when the fin is laid back.

Patches of vomerine and palatine teeth rather large and roundish or quadrangular in shape (Fig. 8E); bands of teeth on tongue elongate, parallel, their posterolateral regions divergent (Fig. 8D).

Color, in formalin, yellowish brown above, furnished with 5 to 12 rather large black ring-like markings; striations of bony tubercles brown; under side of body pale; caudal and dorsal dusky, but other fins pale; peritoneum pale.

REMARKS: Specimens thus far examined agree in general with the original description of *Malthopsis annulifera* Tanaka (1908: 44), but differ from it in having a larger number of pectoral rays (12–14 instead of 8–9) and pointed bony tubercles on the ventral surface instead of flattish plates. Agreement of our specimens with those of *Malthopsis ocellata* Smith and Radcliffe (1912: 207–208, pl. 18, fig. 1, pl. 19, fig. 1) is evident inasmuch as they accord well with it in important features such as the dermal ossicles on body and the rostral and subopercular spines, but differ in that our specimens are provided with a larger number of anal rays (4 instead of 2).

### *Malthopsis lutea* Alcock

Furyu-uo (Japanese name)

Figs. 9, 10

*Malthopsis luteus* Alcock, 1891: 26, pl. 8, figs. 2–2a; (*partim*) Okada and Matsubara, 1938: 458, pl. 113, fig. 1; Herre, 1941: 403; Mori, 1952: 195.

*Malthopsis luteus* (Alcock), Goode and Bean, 1895: 537, fig. 411.

*Malthopsis lutea* Alcock, 1899: 64–65, pl. 19, fig. 4; Kamohara, 1936b: 935; (*partim*) Kamohara, 1938: 76; Kamohara, 1950: 287; Kamohara, 1952: 103.

*Malthopsis kobayashii* Tanaka, 1916: 348.

MATERIAL EXAMINED: Nos. 976, 1635–1637, 47.0–60.0 mm. (60.5–78.0 mm.), off Owasi, Mie Pref., December 6–9, 1935. Nos. 4132–4133, 4292–4294, 4296 and 4679, 47.0–68.0 mm. (58.0–83.0 mm.), off Owasi, January 19, 1937. Nos. 6799–6802, 43.5–62.5 mm. (54.0–77.0 mm.), off Heta, Shizuoka Pref., November 22–24, 1938. Nos. 7053–7055 and 7075–

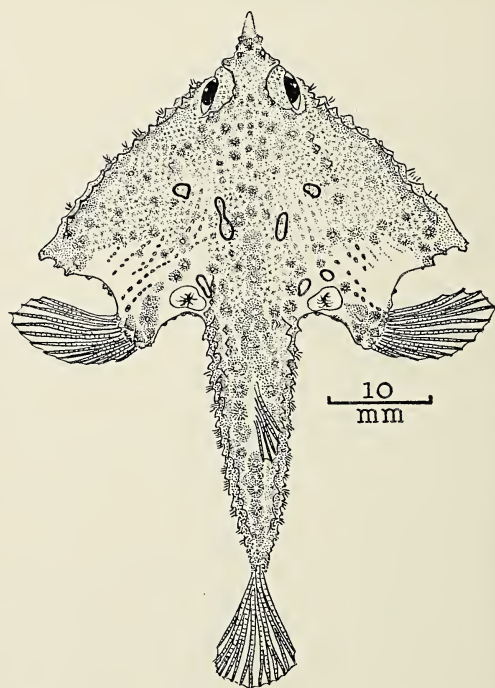


FIG. 9. Dorsal aspect of *Malthopsis lutea* (specimen no. 1637, 47.0 mm. in standard length).

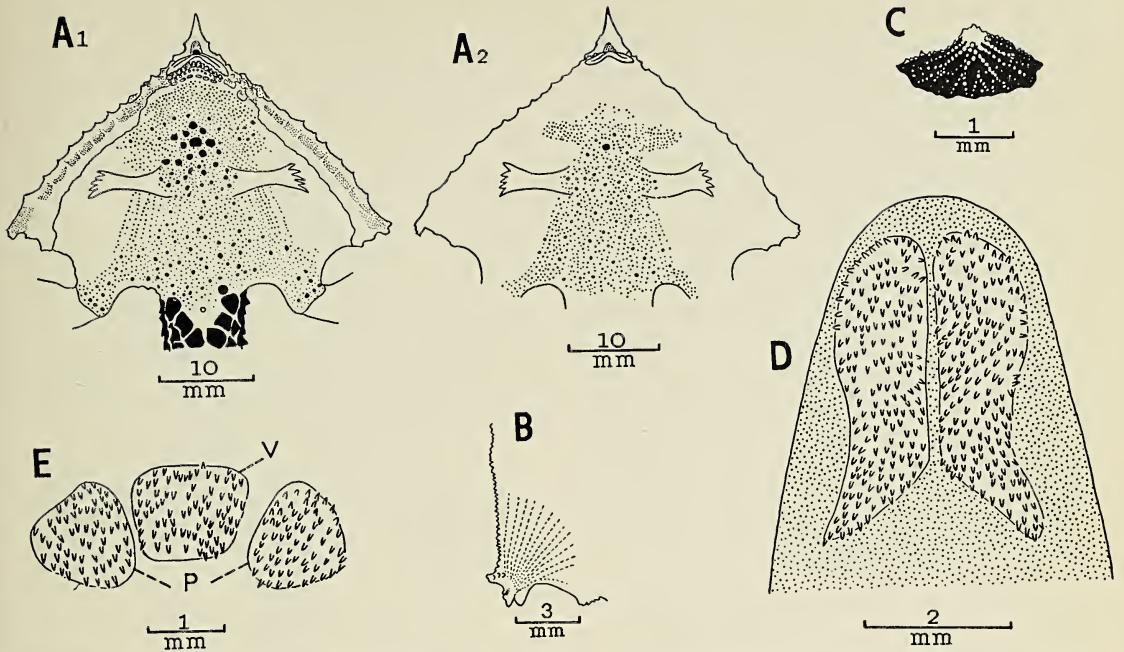


FIG. 10. *M. lutea*: A<sub>1</sub>, ventral aspect of disk; A<sub>2</sub>, dermal prickles on ventral surface of disk; B, subopercular spine; C, lateral aspect of bony tubercles on median line of dorsal surface of disk; D, dorsal surface of anterior part of tongue; E, teeth on palatine (P) and vomer (V). A<sub>1</sub>, from a specimen, 47.0 mm. in standard length (specimen no. 1637); A<sub>2</sub>, from a specimen 68.0 mm. in standard length (specimen no. 4294); B, from a specimen 55.0 mm. in standard length (specimen no. 7259); C, D, and E, from a specimen, 59.5 mm. (specimen no. 7054).

7076, 53.5–60.0 mm. (66.0–74.0 mm.), off Heta, November 24–25, 1939. No. 7259, 55.0 mm. (67.0 mm.), off Heta, January 6, 1940. No. 10368, 54.0 mm. (68.0 mm.), locality and date unknown. No. 15170, 60.0 mm. (76.0 mm.), off Owasi, January 18–20, 1950. No. 19201, 47.0 mm. (58.0 mm.), off Owasi, November 12–17, 1952. Nos. 20817–20820, 44.5–55.0 mm. (57.5–70.0 mm.), locality and date unknown. Nos. 21074–21075, 41.0–64.0 mm. (52.5–82.0 mm.), off Owasi, November 5, 1953.

No. 1992 (the numbers refer to Mie University Fish Collection), 62.5 mm. (78.0 mm.), off Owasi, September 21, 1950. Nos. 4420 and 4422–4423, 54.0–62.5 mm. (68.0–76.5 mm.), off Owasi, February, 1952.

D. 5–6; A. 4; C. 9; P. 11–12. V. 1, 5. Disk length 1.65–1.97 (1.79) in standard length; body width 1.08–1.44 (1.29); tail width 6.30–9.64 (7.73). Disk width 0.58–0.81 (0.71) in

disk length; eye diameter 3.50–5.55 (4.48); interorbital width 6.79–10.00 (8.31); rostral spine 4.66–8.90 (6.63); mouth width 2.95–4.54 (3.88); pectoral fin 2.18–3.86 (2.73); pelvic fin 2.45–3.74 (2.99).

Disk broad, slightly narrower than length of body. Tail rather slender and short. Rostral spine more than half as long as diameter of eye, directed nearly horizontally forward.

Dorsal surface of disk thickly covered with dermal ossicles except for both opercular and shoulder regions; some ossicles enlarged, pointed and quite regular in their arrangement; radial striations of bony tubercles prominent and noticeably serrate (Fig. 10 C); mediolateral row represented by about 4 rather large bony tubercles and joined to median row of tubercles at the anterior part of disk; median row developed throughout the entire length of disk, but several tubercles between those of the mediolateral row smaller



than the posterior ones; occasionally, a number of tubercles scattered on both sides of mediolateral rows. Three rows of bony tubercles running along the antero-lateral margins of disk, the upper turning obliquely upwardly ventrad of posterior rim of eye. Ventral surface of disk, except for lateral regions, thickly covered with minute dermal prickles, some of them, more or less enlarged (Fig. 10 A<sub>1</sub>, A<sub>2</sub>). Tail rather completely surrounded with bony tubercles.

Subopercular spine directed outward and backward, armed at the tip with several minute teeth, but without a prominent antrorse spinule (Fig. 10B).

Sides of body with many dermal cirri. Longest anal ray reaches to base of caudal when the fin is laid back.

Patches of vomer and palatine teeth rather large and quadrangular or circular (Fig. 10E); bands of teeth on tongue elongate, parallel, the posterolateral regions greatly divergent (Fig. 10D).

Color, in formalin, yellowish brown above; pale below; striations of dorsal bony tubercles brown; upper surface of disk sometimes furnished with 2 to 8 large ring-like markings; these markings, however, entirely absent in half of our specimens; caudal, pectoral and dorsal dusky, but the other fins pale; peritoneum also pale.

REMARKS: The specimens belonging to the types V (with the arrangement of the dorsal armature on body irregular and the disk width narrow) and Y (with the dermal armature irregular and the disk width medium) of Lloyd (1909: 175-176, pls. 48-49) are contained within this species.

***Malthopsis tiarella* Jordan**  
Goma-furyu-uo (Japanese name)  
Fig. 11

*Malthopsis tiarella* Jordan, 1902: 378-379, fig. 7; Jordan and Starks, 1904: 628; (*partim*) Jordan, Tanaka, and Snyder, 1913: 428, fig. 396; (*partim*) Tanaka, 1931: 43; ?Kamoha-

ra, 1934b: 1202; ?Oshima, 1938: 285; Kamohara, 1950: 288; Kamohara, 1952: 104.

MATERIAL EXAMINED: No. 4679, 51.5 mm.

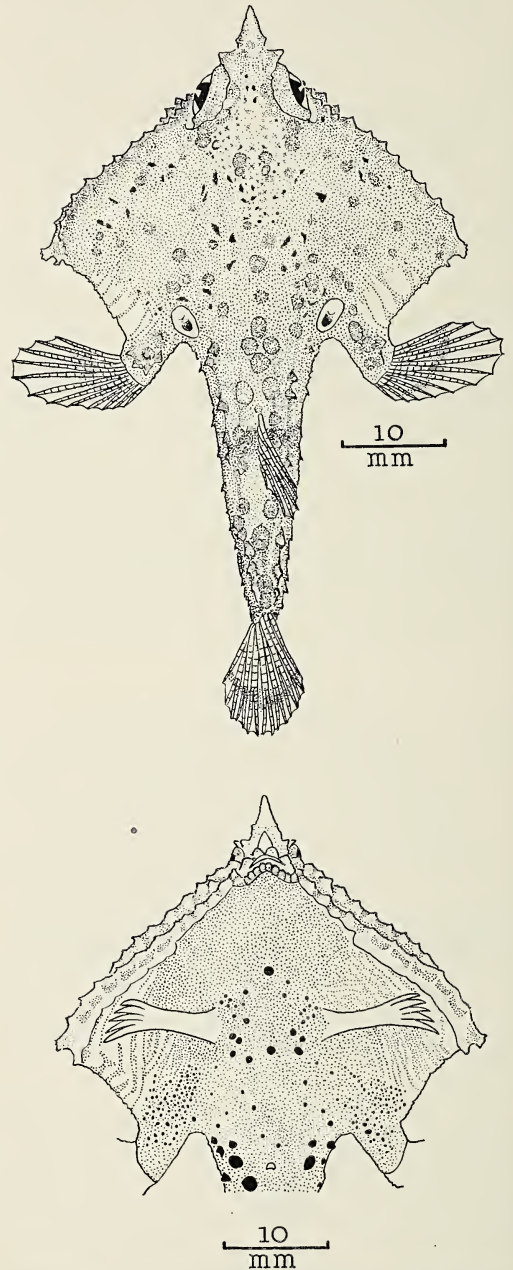


FIG. 11. *Malthopsis tiarella*: Upper figure, dorsal aspect (specimen no. 4679, 51.5 mm. in standard length); lower figure, ventral aspect of disk (specimen no. 4679, 51.5 mm. in standard length).

(64.5 mm.), off Owasi, Mie Pref., January 19, 1937. No. 22068, 37.0 mm. (47.0 mm.), Mimase, Kôchi City, April 10, 1954.

D. 6; A. 3–4; C. 8–9; P. 12; V. 1, 5. Disk length 1.71–1.76 in standard length; disk width 1.31–1.33; tail width 6.70–7.35. Disk width 0.75–0.76 in disk length; eye diameter 4.20–4.60; interorbital width 6.00–7.92; rostral spine 5.20–6.52; mouth width 4.75–5.00; pectoral fin 1.91–2.85; pelvic fin 2.47–3.08.

Disk broad, but narrower than length of body. Tail rather slender and short. Rostral spine nearly porrect, more than half as long as diameter of eye.

Dorsal surface of disk thickly covered with dermal ossicles except for opercle; some of them enlarged, strongly pointed and regular in their arrangement; radial striations of the tubercles prominent and sharply serrate; mediolateral rows each represented by 2–3 rather large tubercles, joining median row at middle of disk; area of forehead between mediolateral rows without any prominent median tubercles. Three rows of tubercles running along the anterolateral margin of disk, the upper row sharply turning obliquely upward ventrad of posterior rim of orbit; the middle row represented by 4 large tubercles, inconspicuous tubercles scattered between the middle and lower rows. Ventral surface of disk almost entirely covered with minute bony prickles, some of them more or less enlarged (Fig. 11). Tail completely surrounded with large and small tubercles.

Subopercular spine directed outward and backward, armed with several minute serrations, but without any prominent spinules.

Lateral sides of body without dermal cirri. Longest anal ray reaches to base of caudal when the fin is laid back.

Patches of vomerine and palatine teeth rather large and quadrangular.

Color, in formalin, brownish above, with irregular blackish brown specks; back and side of tail crossed with black bars at the base of dorsal and caudal; pale below; a dark bar

crossing near the end of caudal; pectoral and pelvic dusky; anal pale.

REMARKS: It should be noted that *Malthopsis tiarella* is shown in Jordan's figure (1902, fig. 7) with more numerous pectoral and caudal rays than those given by Jordan in his original description of this species (14 and 9 respectively instead of 10 and 6). We are inclined to regard these discrepancies partly as Jordan's miscounting and partly as draughtsman's errors. Although the dorsal rays are somewhat fewer in our two specimens than in the holotype (6 instead of 7), the agreement in other various important features between our specimens and the holotype are beyond doubt. The species is most closely related to *Malthopsis lutea* Alcock, but may be distinguished from it by the following features: bony tubercles on dorsal surface forming two rows on forehead; upper surface of disk provided with blackish brown irregular specks; dorsal rays six or seven.

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## Description of a New Species of *Elytrurus* and a Catalogue of the Known Species (Coleoptera: Curculionidae: Otiorhynchinae)

ELWOOD C. ZIMMERMAN<sup>1</sup>

SIR GUY MARSHALL has asked me to describe a new species of *Elytrurus* which was collected on Niue Island by A. C. Gerlach and sent to the Commonwealth Institute of Entomology for identification by W. Cottier, Department of Scientific and Industrial Research, New Zealand. I am pleased to describe the new species, because it is the first to be found on the island of Niue, and it thus fills another gap in the knowledge of the distribution of this interesting genus of broad-nosed weevils. Niue (lat. 19° 02' S, long. 169° 55' W) lies south of Samoa, and Vavau, Tonga, which is about 240 miles to the west, is the nearest island. Niue is an emerged coral island which rises somewhat more than 200 feet above sea level. The flora is quite varied for a small coral island, and considerable areas of forest remain. It is unfortunate that so little is known about the insect fauna of the island.

With this new species it is appropriate to present a catalogue of *Elytrurus* and append some notes on the geographical distribution of the genus and its relationship to *Rhyncogonus*. In the Pacific east of Samoa, *Elytrurus* is replaced by the genus *Rhyncogonus* the appearance and habits of which are very similar

to those of *Elytrurus* (see Fig. 1). In no island, however, do both genera occur together, and the reason for the unusual distributions of the two groups has not yet been discovered. The eastern-most species of *Elytrurus* occur in Samoa, and the Samoan forms are the most divergent of the genus. I have collected several thousand specimens of the two genera, and they appear to be counterparts. The eggs of *Rhyncogonus* are deposited on leaves, and the young larvae drop to the ground to make their way to the roots of plants where they feed. I presume that *Elytrurus* has similar habits, but I did not search for their early stages during my expeditions to Samoa and Fiji.

The new species and *Elytrurus cinctus* Boisdual, to which it is most closely allied, share the character of reduction in the development of the bevel of the corbel of the hind tibia, a tendency toward the formation found in *Rhyncogonus*. In *Rhyncogonus* the bevel is obsolete, and this character has been found useful in separating the two genera. However, it has not been pointed out that there is much variation in the development of the corbel in *Elytrurus*, and without an expert knowledge of the formation of the bevel in these genera, one might easily be led astray. In its most highly developed form the bevel is a prominently differentiated, shiny area set off obliquely or angularly from the outer face of the tibia, and entirely surrounded on the inner

<sup>1</sup> This research was completed at the British Museum (Natural History) during the tenure of a United States National Science Foundation grant, and this paper is a tangent contribution to the project "Insects of Hawaii." Manuscript received August 23, 1955.



FIG. 1. Map showing the distribution of the genera *Elytrurus* ("E") and *Rhyncogonus* ("R").

(tarsal) and outer (ectal face) sides by a dense palisade of stiff spines. In many species of *Elytrurus*, including the new species and *cinctus*, the outer row of bristles has been almost entirely lost. In *Rhyncogonus* there is no trace of the outer palisade of bristles, and at most only the faintest indication of an area which might be interpreted as an indication of the remnant of a bevel can be distinguished in some species. The eyes of *Elytrurus* are larger and flatter than those of *Rhyncogonus*. Many species of *Rhyncogonus* have strongly protuberant eyes.

Marshall (1938: 71) noted of *Elytrurus* that "An exceptional type of dimorphism is to be found in the first segment of the hind tarsi: in the male this segment is clothed beneath with soft hairs; but in the female its inner edge on the basal half is set with stiff spines, which are sometimes bare and sometimes hidden by hairs." This statement appears to apply only to certain species, and it is not characteristic of the genus as a whole.

The adult weevils feed upon the leaves of plants, and many species are abundant and voracious feeders. Plants such as *Piper* are frequently heavily attacked. It is possible that some species may become pests in areas where cultivated crops are grown adjacent to native forests or in clearings in the forest. One species, *griseus*, has become very widespread in the Fijian islands, evidently through the aid of man. Should certain of the species be carried to other regions and become established some damage to economic crops might occur. The larvae are, as noted above, presumed to feed underground at the roots of plants.

The described species of *Elytrurus* are distributed from west to east as follows:

SOLOMONS—1 species  
*anensis*

SANTA CRUZ—1 species  
*lapeyrousei*



## NEW HEBRIDES—14 forms

<i>alatus</i>	<i>maculicollis</i>
<i>ambrymensis</i>	<i>marginatus</i>
<i>aobae</i>	<i>risbeci</i>
<i>caudatus</i>	<i>rusticus</i>
<i>caudatus erromangoi</i>	<i>santicolus</i>
<i>convexus</i>	<i>tannae</i>
<i>divaricatus</i>	<i>tannae erromangoana</i>

## FIJI—23 forms

<i>acuticauda</i>	<i>matukuanus</i>
<i>bryani</i>	<i>moalensis</i>
<i>cervinus</i>	<i>obtusatus</i>
<i>durvillei</i>	<i>painei</i>
<i>evansi</i>	<i>prasinus</i>
<i>expansus</i>	<i>protensus</i>
<i>forcipatus</i>	<i>simmondsi</i>
<i>granatus</i>	<i>smaragdus</i>
<i>greenwoodi</i>	<i>subangulatus</i>
<i>griseus</i>	<i>subtritus</i>
<i>griseus taveuni</i>	<i>subvittatus</i>
<i>leveri</i>	

## TONGA—1 species

*cinctus*

## NIUE—1 species

*niuei*

## SAMOA—3 forms

<i>bicolor</i>	<i>samoensis setiventris</i>
<i>samoensis</i>	

*Elytrurus niuei* Zimmerman, new species  
Figs. 2-4

COLOR: derm mostly reddish brown, venter mostly darker to nearly black; vestiture mostly creamy white, but with iridescent scales (evidently subject to fading) more abundant on lower surface; scaling denser and more conspicuous on dorsum of female than male, in latter sex the scales form a pale vitta on sides from anterior margin of pronotum to apex of elytra.

STRUCTURE: *Head* with sides, as viewed from above, nearly evenly arcuate from pronotum to apices of eyes, eyes not obviously interrupting this contour; breadth at hind margins of eyes distinctly greater than length from pronotum to anterior edge of an eye (1.75:1.2); length, measured from side, from pronotum to anterior edge of eye equal to distance between fore edge of eye and base of mandible; distance between pronotum and eye equal to length of eye; narrowest frontal interocular distance only a little more than one-half the breadth between hind margins of eyes (10:18); interocular area with a conspicuous median pit which marks the termination of the raised median line or median

FIG. 2. *Elytrurus niuei*, new species, holotype male.



FIG. 3. *Elytrurus niuei*, new species, allotype female.

carina from pit to epistome; crown and front with shallow punctures of medium size interspersed with some minute punctures, most of the larger punctures bearing conspicuous, decumbent setae which are directed toward the midpoint of the crown; scales oval, densest along upper margins of eyes, rather densely continued ventrad to bare median gular sutural line.

*Rostrum* with greatest preapical breadth subequal to length from fore edge of eye to apex of mandible, longitudinal dorsal contour flattened from just behind interocular pit; sides beneath scrobes continuously squamose with sides of head and with numerous, conspicuous, slanting, erect setae; dorsum impressed on either side of median line which is consequently elevated as a median carina whose development is variable and may be conspicuous or obscure, punctate, squamose and setose as head; epistome rather densely set with mostly small punctures, setose only at sides and without squamae; mentum not setose, with a peduncle about one-fourth to one-third as long as median length of mentum.

*Antennae* with scape comparatively densely clothed with prostrate, narrow, mostly almost

setiform scales, which are more squamiform on dorsal edge, and longer, decumbent setae, apex not quite reaching as far back as anterior one-fourth of side of pronotum, subequal in length to the seven funicular segments combined; funiculus with vestiture less dense and finer than scape, lengths of segments as follows: 1-20, 2-22, 3-12, 4-11, 5-10, 6-10, 7-10; club as long as preceding four funicular segments together, lengths of segments: 1-15, 2-12, 3-15, greatest thickness of segment two 12 (these measurements with micrometer reading 40 units to one millimeter).

*Pronotum* obviously transverse (28:20), broadest at or just behind middle, anterior margin broadly, shallowly emarginate, posterior margin weakly convex; longitudinal median contour only slightly arcuate; disc punctate-granulate, the punctures on the posterior sides of the granules bearing fine, decurved setae mostly directed obliquely backward toward median line; scales on disc smaller and sparser than on sides, not covering the granules which protrude and are moderately shiny; squamae larger, denser, imbricated on side margins.



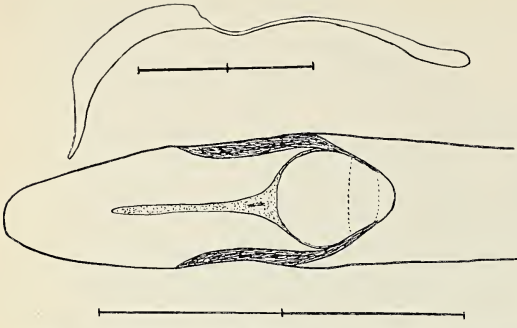


FIG. 4. Aedeagus of *Elytrurus ninei*, new species; upper figure, lateral aspect; lower figure, dorsal aspect of distal part; total length of each scale line is 1.0 mm.

*Scutellum* broadly protuberant, disc not punctured, not squamose, not setose, rather shiny, very finely alutaceous.

*Elytra* as illustrated, a little more than three times as long as pronotum, apices only shortly and moderately divaricate; apical processes reduced to low bosses which hardly project behind apex; sides not evenly arcuate into base, but humeri rather straightly oblique; striae not impressed between the rows of moderately sized stria punctures which are separated from each other on disc about the diameter of a puncture or slightly farther, the punctures bearing from their anterior ends decumbent squamiform setae; intervals flat, about two or three times as broad as stria punctures, each bearing a row of small granules from the posterior ends of which arise decurved setae; squamae oval, not imbricated on disc, even on females which have denser scaling, squamae denser and with considerable imbrication on epipleurae.

*Sternum* squamose and setose; prosternum with posterior median process strongly protuberant; mesosternum with intercoxal process bluntly subtriangular, apex less than one-third as broad as breadth of coxa, densely squamose, exocoxal area conspicuously more densely squamose than episternum, squamae strongly imbricated, scales on episternum separated, those on epimeron smaller and less numerous; metasternum at the shortest distance between mid and hind coxae subequal

in length to transverse diameter of a mesocoxa, disc tending to be transversely strigate, squamae there smaller and much sparser than on sides where they are dense but interrupted by rather large setigerous punctures; metasternum squamose and setose.

*Legs* squamose and setose, femora more densely squamose than tibiae, but scales not imbricated and not forming patches on outer or dorsal sides; posterior femora extending to beyond base of fifth ventrite; legs similar in the two sexes, anterior tibiae not modified in male; mucrones small on all tibiae; all tibiae with a row of heavy, stiff spines along inner edge in addition to the long stiff setae; corbels of hind tibiae with the bevel considerably reduced and tending toward obsolescence, without a sharp upper line marking the upper (outer) edge of the bevel and without the row of stiff spines or heavy bristles along the upper margin as is found on many species of the genus, although the main (lower, or inner) row of spines separating the bevel from the corbel proper is well developed and normal.

*Venter* with puncturation moderate, with numerous slanting setae on all ventrites; with scales larger, denser and more conspicuous on sides of segments, those on discs of ventrites one to four narrow and becoming setiform caudad, a wide patch of scales on sides of ventrite four in male, but only a few scales there in female; ventrite five with only a few broad scales at sides at base in male, but apical two-thirds of disc of female clothed with broad and narrow lanceolate scales; with the first ventrite about as long along median line as ventrite two plus three, rather similar in the two sexes; ventrite two as long as three plus four plus about one-half of four again; ventrite five broadly U-shaped, two-thirds as long as wide and more than one-fifth shorter than ventrite one in male, V-shaped, only a little shorter than wide and as long as ventrite one in female, also in the female it is bare in about basal one-third, this bare area has a sublateral groove on either side from base to squamose zone.

LENGTH (including head and rostrum): male, 10–10.5 mm.; female, 12–12.5 mm. Breadth: male, 4.25–4.5; female: 5.25.

Holotype male and allotype female, deposited in the British Museum (Natural History), one male and one female paratype collected by A. C. Gerlach "ex coconut tree" at Fonuakula, Niue Island, in 1953.

This species most closely resembles *Elytrurus cinctus* Boisduval from Tonga, and it appears to have been derived from it. *Elytrurus cinctus* is a larger, mostly black-bodied species with the dorsum conspicuously clothed with green or coppery scales and with a broader, much more conspicuous lateral pale band. The pit between the eyes is a deep hole on *niuei*, but it is shallow or obsolete on *cinctus*. The side of the rostrum beneath the scrobe is densely and conspicuously squamose in *niuei* (and also setose), but in *cinctus* it is only setose. The eyes are somewhat flatter in *niuei* and do not interrupt the lateral outline of the head as much as they do in *cinctus*. The anterior margin of the pronotum is not emarginate in *cinctus* as it is in *niuei*. The fifth ventrite of the female of *cinctus* has the scales reduced to setae or there are a few narrowly lanceolate scales, but on *niuei* there are obviously numerous broader ovoid or broader lanceolate scales.

#### ELYTRURUS Boisduval

*Elytrurus* Boisduval, 1835: 400. Schoenherr, 1843: 238. Lacordaire, 1863: 147. Faust, 1897: 230.

*Elytrogonus* Guérin-Ménéville, 1841: 126. Lacordaire, 1863: 148. Faust, 1897: 231. Lona, 1937: 302.

Synonymy by Marshall, 1938: 71. Lona, 1937: 302, catalogue. Lona incorrectly credited *Elytrurus* to Schoenherr and incorrectly listed it as a synonym of *Elytrogonus*. Marshall, 1938: 69, revision and key. Paulian, 1945: 193, discussion and key. Type of the genus: *Elytrurus lapeyrousei* Boisduval, 1835: 400. Cited by Schoenherr, 1843: 239.

The following species have been described in *Elytrurus* or *Elytrogonus* but are synonyms or have been transferred to other genera:

*Elytrurus Angulatus* Waterhouse is a synonym of *Elytrurus expansus* Waterhouse.

*Elytrurus bivittatus* Marshall is a synonym of *Elytrurus bicolor* Marshall.

*Elytrogonus coquereli* Fairmaire is a *Rhyncogonus*.

*Elytrurus dentipennis* Fairmaire is a synonym of *Elytrurus caudatus* Pascoe.

*Elytrogonus griseus* Montrouzier is an *Anomalodermus*.

*Elytrurus horizontalis* Fairmaire is a synonym of *Elytrurus subvittatus* Pascoe.

*Elytrogonus otiorhynchoides* Fairmaire is a *Rhyncogonus*.

*Elytrurus* (?) *papuanus* Heller is a *Hellerbinus*.

*Elytrurus serrulatus* Waterhouse is a synonym of *Elytrurus rusticus* Pascoe.

*Elytrurus squamatus* Rainbow is a synonym of *Trigonops insularis* (Boheman).

*Elytrurus vanikorae* Heller is a synonym of *Elytrurus lapeyrousei* Boisduval.

#### CATALOGUE OF THE SPECIES

1. *acuticauda* Fairmaire (1879: 46; 1880: 208); Marshall (1938: 90, fig. 14); Paulian (1945, fig. 55).

*Elytrogonus acuticauda* (Fairmaire) Lona (1937: 302).

Fiji: Taveuni.

2. *alatus* Saunders and Jekel (1855: 290, pl. 15, fig. 1); Lacordaire (1863: 148); Marshall (1938: 90).

*Elytrogonus alatus* (Saunders and Jekel) Lona (1937: 302).

New Hebrides: Futuna.

In *Coleopterorum Catalogus*, the locality is given as Lord Howe Island, but this Futuna should not be confused with the Lord Howe Island between Australia and New Zealand or Ontong Java ("Lord Howe") or Futuna, Horne Islands west of Samoa.

3. *aobae* Paulian (1945: 199, figs. 46, 47). New Hebrides: Omba (Oba, Aoba).



4. **ambrymensis** Marshall (1938: 81); Paulian (1945, figs. 43, 66).  
New Hebrides: Ambrim (Ambrym).
5. **anensis** Marshall (1938: 82).  
Solomons: Santa Ana.
6. **bicolor** Marshall (1921: 588; 1931: 260, fig. 3; 1938: 76).  
*Elytrogonus bicolor* (Marshall) Lona (1937: 302).  
*Elytrurus bivittatus* Marshall (1921: 588); synonymy by Marshall (1931: 260).  
Samoa: Tutuila, Upolu, Savaii. Type locality cited only as "Samoan Islands."
7. **bryani** Marshall (1938: 84, fig. 7).  
Fiji: Naiau.
8. **caudatus** Pascoe (1870: 471, pl. 18, fig. 5); Fairmaire (1880: 209); Marshall (1938: 89, fig. 13); Paulian (1945, fig. 61).  
*Elytrogonus caudatus* (Pascoe) Lona (1937: 302).  
*Elytrurus dentipennis* Fairmaire (1879: 46; 1880: 209); synonymy by Marshall (1938: 89).  
*Elytrogonus dentipennis* (Fairmaire) Lona (1937: 302).  
New Hebrides: Tana (Tanna).  
This species has erroneously been recorded from Fiji by Fairmaire (1879: 46; 1880: 209) and others.
9. **caudatus erromangoi** Paulian (1945: 196, figs. 49, 61, 62).  
New Hebrides: Eromanga (Erromango).  
The status of this form requires further study; it may be a species.
10. **cervinus** Marshall (1938: 76, fig. 1).  
Fiji: Ovalau.
11. **cinctus** Boisduval (1835: 401); Bohe-man (1843: 240); Fairmaire (1849: 511; 1880: 211); Lacordaire (1863: 148); Marshall (1938: 80); Paulian (1945: 197, figs. 39, 58).  
*Elytrogonus cinctus* (Boisduval) Lona (1937: 302).  
Tonga: Neiafu (Vavau Group), Vavau, Tongatabu.  
Specimens have been seen in collections
- which bear incorrect locality labels. Boisduval originally stated erroneously that it came from Vanikoro (Santa Cruz Islands). In *Coleopterorum Catalogus*, the localities "Neue Hebriden, Vanikor, Tanga" (all in error) are given. Paulian (1945: 197) records it from Fiji in error. Fairmaire (1880: 211) pointed out the errors in locality and gave the true locality as Tonga. Numerous specimens, all from Tonga, have been seen.
12. **convexus** Paulian (1945: 201, fig. 35).  
New Hebrides: Espiritu Santo.
13. **divaricatus** Waterhouse (1877: 10); Fairmaire (1880: 212); Marshall (1938: 82); Paulian (1945, fig. 53).  
*Elytrogonus divaricatus* (Waterhouse) Lona (1937: 302).  
New Hebrides: Ambrim (Ambrym), Efate (Vati, type locality).
14. **durvillei** Blanchard (1853: 221); Fairmaire (1880: 210); Lacordaire (1863: 148); Marshall (1938: 93); Paulian (1945, figs. 48, 69).  
*Elytrogonus Durvillei* (Blanchard) Lona (1937: 303).  
Fiji: Vanua Levu.  
Erroneously listed in *Coleopterorum Catalogus* from "Labouka" (error for Levuka, Ovalau).
15. **evansi** Marshall (1938: 82, fig. 6).  
Fiji: Taveuni.
16. **expansus** Waterhouse (1877: 8); Fairmaire (1880: 207); Marshall (1938: 90, figs. 15, 16).  
*Elytrogonus expansus* (Waterhouse) Lona (1937: 303).  
*Elytrurus angulatus* Waterhouse (1877: 8); synonymy by Fairmaire (1880: 208).  
Fiji: Ovalau (type locality), Viti Levu.  
In *Coleopterorum Catalogus*, Ovalau is misspelled Ovalan.
17. **forcipatus** Marshall (1938: 85, fig. 8).  
Fiji: Tuvutha (Lau Group).
18. **granatus** Fairmaire (1879: 46 [misprinted in Marshall as p. 116]; 1880: 210); Marshall (1938: 93); Paulian (1945, figs. 67, 68).

- Elytrogonus granatus* (Fairmaire) Lona (1937: 303).  
Fiji: Taveuni (possible type locality), Viti Levu.
19. **greenwoodi** Marshall (1938: 94, figs. 20, 21).  
Fiji: Viti Levu.
20. **griseus** (Guérin-Ménéville).  
*Elytrogonus griseus* Guérin-Ménéville (1841: 126; type of *Elytrogonus*); Blanchard (1853: 237, pl. 15, figs. 1, 2); Lacordaire (1863: 149); Fairmaire (1881: 293); Lona (1937: 303).  
*Elytrurus griseus* (Guérin-Ménéville) Marshall (1938: 78).  
Fiji: Matuka, Moala, Ovalau, Taveuni, Totoya, Vanua Levu, Viti Levu, Wakaya. Lau Group: Avea, Kambara, Kanathea, Katafanga, Komo, Lakemba, Mango, Mothe, Naiau, Namuka, Oneata, Thithia, Tuvutha, Vanua Mbalavu, Vanuavatu.
- In the original description the type locality was erroneously stated to have been Triton Bay, New Guinea, but the species is Fijian. Marshall misspelled Totoya as Totova, and Oneata as Onesta.
- It is interesting that this one species should have become so widespread through the islands, whereas most of the other species have restricted distributions. It is the commonest species of *Elytrurus*, and its habits appear to have contributed to its distribution by the aid of man. It may at times become a minor pest.
21. **griseus taveuni** Marshall (1938: 78, as subspecies of *griseus*).  
Fiji: Taveuni.
22. **lapeyrousei** Boisduval (1835: 400); Lacordaire (1863: 148); Marshall (1938: 88); Paulian (1945: 196, fig. 57).  
*Elytrurus Lapeyrousei* Boisduval, Boheman, in Schoenherr (1843: 239).  
*Elytrogonus Lapeyrousei* (Boisduval) Lona (1937: 303).  
*Elytrurus vanikorae* Heller (1935: 269); synonymy by Marshall (1938: 88); Paulian (1945: 195, footnote, fig. 38; this species?).  
*Elytrogonus vanikorae* (Heller) Lona (1937: 304).  
Santa Cruz Islands: Vanikoro.  
Type of the genus.
23. **leverii** Marshall (1938: 92).  
Fiji: Vanua Levu.
24. **maculicollis** Heller (1916: 358); Marshall (1938: 82); Paulian (1945: 196, figs. 41, 42, 44, 45, 63).  
*Elytrogonus maculicollis* (Heller) Lona (1937: 303).  
New Hebrides: Epi (type locality), Malekula.
25. **marginatus** Saunders and Jekel (1855: 291, pl. 15, fig. 2); Lacordaire (1863: 148); Marshall (1938: 86); Paulian (1945, fig. 54).  
*Elytrogonus marginatus* (Saunders and Jekel) Lona (1937: 303).  
New Hebrides: Aneityum (Aneiteum), Eromanga.
- In *Coleopterorum Catalogus* it is erroneously listed from "Lord Howe." The exact type locality is unknown.
26. **matukuanus** Marshall (1938: 79).  
Fiji: Matuku.
27. **moalensis** Marshall (1938: 87).  
Fiji: Moala.
28. **niuei** Zimmerman, new species.  
Niue Island.
29. **obtusatus** (Fairmaire).  
*Elytrogonus obtusatus* Fairmaire (1881: 293); Lona (1937: 303).  
*Elytrurus obtusatus* (Fairmaire) Marshall (1938: 78); Paulian (1945: fig. 64).  
Fiji: Viti Levu.
30. **painei** Marshall (1938: 80, figs. 4, 5).  
Fiji: Mbengga.
31. **prasinus** Marshall (1938: 87, figs. 10, 11).  
Fiji: Kandavu.
32. **protensus** Marshall (1938: 93, fig. 19).  
Fiji: Viti Levu.
33. **risbeci** Marshall (1937: 39; 1938: 80, fig. 3); Risbec (1937: 157, pl. 1, fig. 13);



- Paulian (1945: 196, figs. 40, 56).  
*Elytrogonus Risbeci* (Marshall) Lona (1937: 303).  
 New Hebrides: Efate (Vate).
34. **rusticus** Pascoe (1881: 589); Fairmaire (1881: 292); Marshall (1938: 80); Paulian (1945, fig. 70).  
*Elytrogonus rusticus* (Pascoe) Lona (1937: 303).  
*Elytrurus serrulatus* Waterhouse (1897: 10); Fairmaire (1880: 212); synonymy by Marshall (1938: 80).  
*Elytrogonus serrulatus* (Waterhouse) Lona (1937: 303).  
 New Hebrides: Aneityum ?, Efate (Vate, Vati), Tana (Tanna).  
 Erroneously recorded by Fairmaire (1881: 292) from Fiji, and the error repeated in *Coleopterorum Catalogus*. In Marshall (1938: 80) delete the "1877" after Waterhouse.
35. **samoensis** Marshall (1921: 587; 1938: 76).  
*Elytrogonus samoensis* (Marshall) Lona (1937: 303).  
 Samoa (exact type locality not known).
36. **samoensis setiventris** Marshall (1921: 587, a variety).  
*Elytrogonus samoensis setiventris* (Marshall) Lona (1937: 303).  
 Samoa: Tutuila.  
 Marshall did not mention this form in his monograph of the Samoan Curculionidae (1931) or in his revision of *Elytrurus* (1938).
37. **santicolus** Marshall (1938: 77).  
 New Hebrides: Espiritu-Santo.
38. **simmondsi** Marshall (1938: 90, fig. 17).  
 Fiji: Viti Levu.
39. **smaragdus** Marshall (1938: 88, fig. 12).  
 Fiji: Kandavu.
40. **subangulatus** (Fairmaire).  
*Elytrogonus subangulatus* Fairmaire (1883: 34); Lona (1937: 303).  
*Elytrurus subangulatus* (Fairmaire) Marshall (1938: 79).  
 Fiji: Viti Levu.  
 Originally recorded in error from Duke of York Island by Fairmaire.
41. **subtritus** Marshall (1938: 92, fig. 18).  
 Fiji: Ovalau.
42. **subvittatus** Pascoe (1881: 589); Fairmaire (1881: 291); Marshall (1938: 86).  
*Elytrogonus subvittatus* (Pascoe) Lona (1937: 303).  
*Elytrurus horizontalis* Fairmaire (1881: 291); synonymy by Marshall (1938: 86).  
*Elytrogonus horizontalis* (Fairmaire) Lona (1937: 303).  
 Fiji: Ovalau, Ngau (exact type locality not known, but probably Ovalau).
43. **tannae** Paulian (1945: 197, fig. 51).  
 New Hebrides: Tana (Tanna).
44. **tannae erromangoana** Paulian (1945: 198, fig. 52).  
 New Hebrides: Erromanga (Erromango).  
 The status of this form requires study; it may be a species.

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## Taxonomic Considerations of the Lantern Fish *Polyipnus spinosus* Günther and Related Species

YAICHIRO OKADA and KIYOSHI SUZUKI<sup>1</sup>

THE THREE SPECIES treated in this paper (*Polyipnus spinosus* Günther, *P. stereope* Jordan and Starks, and *P. trigentifer* McCulloch) are rather rare lantern fishes belonging to the family Sternoptychidae. *P. spinosus* (Fig. 1) is a deep sea species known to occur off the Philippines, Borneo, in the Gulf of Guinea, off Cape Morgan, Natal coast, in the Andaman Sea, Suruga Bay, and Kumano-Nada, Japan. *P. stereope* has been taken in Sagami Bay, Suruga Bay, and Kumano-Nada, Japan. *P. trigentifer* is known only from the Great Australian Bight. Several ichthyologists have presented opinions on the relationship of these species but their validity has remained in doubt.

In 1887 Günther described *Polyipnus spinosus* from a specimen obtained from the deep sea between the Philippines and Borneo. Subsequently Alcock (1889), Wood-Mason and Alcock (1891), Goode and Bean (1895), Brauer (1906), Weber and de Beaufort (1913), Barnard (1925), Fowler (1936), Parr (1937), Schultz (1938), and Matsubara (1941, 1950) have also described this species. In 1904 Jordan and Starks described *Polyipnus stereope* based on a specimen collected by the U.S. Fish Commission Steamer "Albatross" from Sagami Bay, and remarked that this species differs from *Polyipnus spinosus* Günther in the

character of the posttemporal process. In 1914 McCulloch described *Polyipnus trigentifer* as a new species based on many specimens collected from the Great Australian Bight. At the end of his description of *Polyipnus trigentifer* he noted that this species is very near to *Polyipnus spinosus* Günther and *Polyipnus stereope* Jordan and Starks but has more dorsal and anal rays, a greater number of anal photophores, and a much greater development of the posttemporal process.

The amalgamation of these three species into one has been proposed by Schultz and by Matsubara. In 1938, in his review of the fishes of the genera *Polyipnus* and *Argyropelecus* (Family Sternoptychidae), Schultz considered *Polyipnus stereope* Jordan and Starks and *Polyipnus trigentifer* McCulloch to be synonyms of *Polyipnus spinosus* Günther. In 1941, Matsubara described the fishes of the genus *Poly-*

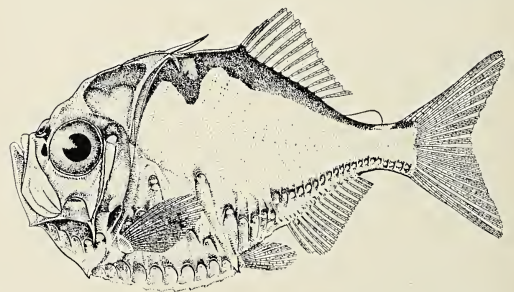


FIG. 1. *Polyipnus spinosus* Günther, natural size. (No. 4810, Kumano-Nada.)

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*ipnus* found in Suruga Bay and concurred in Schultz's opinion concerning *Polyipnus spinosus* Günther. Furthermore, in 1952, in his examination of the fishes of the genus *Polyipnus* taken from Kumano-Nada, Matsubara treated *Polyipnus stereope* Jordan and Starks and *Polyipnus trigentifer* McCulloch as synonyms of *Polyipnus spinosus* Günther.

Among the fishes obtained off Owashi, Mie Prefecture, in November, 1953, and April, 1954, at a depth of about 200 fathoms, were 130 specimens of the genus *Polyipnus*. Upon careful examination of these specimens and a review of the descriptions given by various authors we came to the conclusion that there exist two distinct forms among these specimens and that 98 are referable to *Polyipnus spinosus* Günther and 32 to *Polyipnus stereope* Jordan and Starks. A distinction between the two is obvious in such body proportional characters as depth at origin of dorsal, depth at the end of dorsal, depth of caudal peduncle, and length of posttemporal process in relation to body length, and in such meristic characters as number of gill rakers on the first gill arch and number of pectoral fin rays. These differences are here considered in detail.

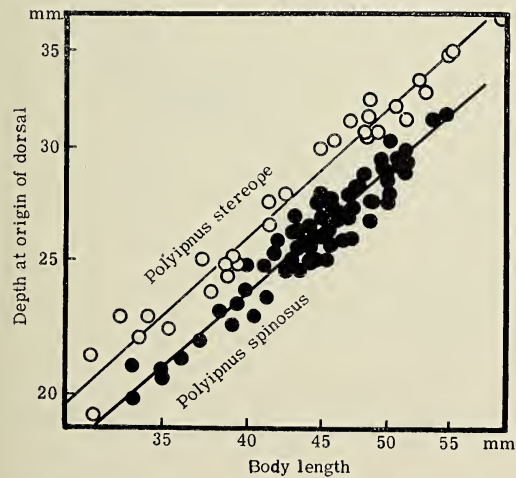


FIG. 2. The allometric lines of depth at origin of dorsal-body length in *Polyipnus spinosus* and *P. stereope*.

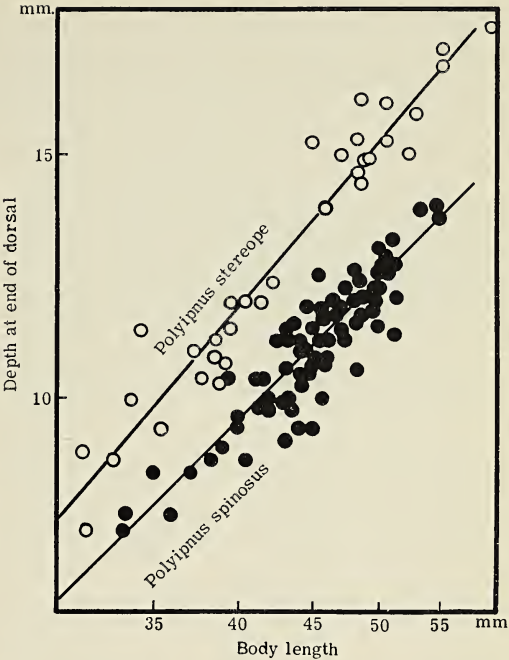


FIG. 3. The allometric lines of depth at end of dorsal-body length in *Polyipnus spinosus* and *P. stereope*.

Body Proportional Characters

Huxley's allometric equation<sup>2</sup> is respectively applied to the four body parts to the body length in order to define the difference of the quantitative morphogenesis of these body parts between *P. spinosus* and *P. stereope*. The growth coefficient and initial growth index in samples of each body part to the body length in two allometric lines are indicated in Table 1.

For the two allometric lines of four body parts to the body length, a test of significance of "slope differences" and "positional differences" was respectively carried out. The results are:

- a. Depth at origin of dorsal-body length relationship (Fig. 2, Table 2). As indicated

<sup>2</sup> The equation is now generally written  $y = bx^\alpha$ , and is termed the single allometric formula. It may be given the form  $\log y = \log b + \alpha \log x$  ( $y = b + \alpha x$ ), showing that when the logarithms of two dimensions  $x$  and  $y$  obeying the law are plotted against one another, the points lie along a straight line.



TABLE 1  
GROWTH COEFFICIENT ( $\hat{\alpha}$ ) AND INITIAL GROWTH INDEX ( $\hat{b}$ ) IN SAMPLE  
OF FOUR BODY PARTS TO THE BODY LENGTH

	<i>Polyipnus spinosus</i>		<i>Polyipnus stereotype</i>	
	$\hat{\alpha}$	$\hat{b}$	$\hat{\alpha}$	$\hat{b}$
(a) Depth at origin of dorsal.....	0.89682	-0.06331	0.93898	-0.09277
(b) Depth at end of dorsal.....	1.05345	-0.70645	1.22516	-0.89722
(c) Depth of caudal peduncle.....	0.72965	-0.52539	0.95444	-0.77841
(d) Length of posttemporal process.....	0.54217	0.16408	0.55194	0.08096

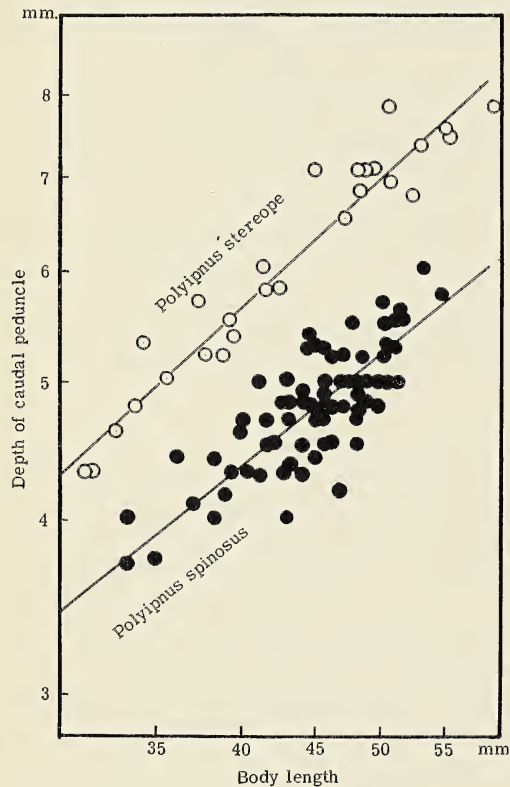


FIG. 4. The allometric lines of depth of caudal peduncle-body length in *Polyipnus spinosus* and *P. stereotype*.

in Table 2, there is no significant difference with "slope," but the "positional difference" is obviously significant (level of significance, 1 per cent).

b. Depth at end of dorsal-body length relationship (Fig. 3, Table 3). As indicated in Table 3, the two lines have different

- "slopes" (level of significance, 5 per cent) and "positions" (level of significance, 1 per cent).
- c. Depth of caudal peduncle-body length relationship (Fig. 4, Table 4). As indicated in Table 4, the "slopes" and "positions" representing the two allometry lines are significantly different (level of significance, 1 per cent in each case).
- d. Length of posttemporal process-body length relationship (Fig. 5, Table 5). As indicated in Table 5, there is no significant difference with "slope," but the "positional difference" is obviously significant (level of significance, 1 per cent).

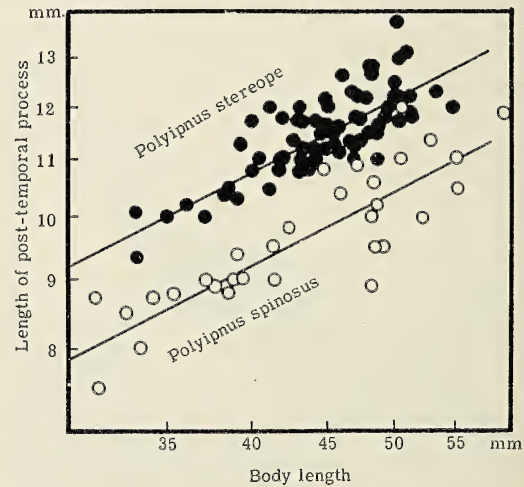


FIG. 5. The allometric lines of length of the post-temporal process-body length in *Polyipnus spinosus* and *P. stereotype*.

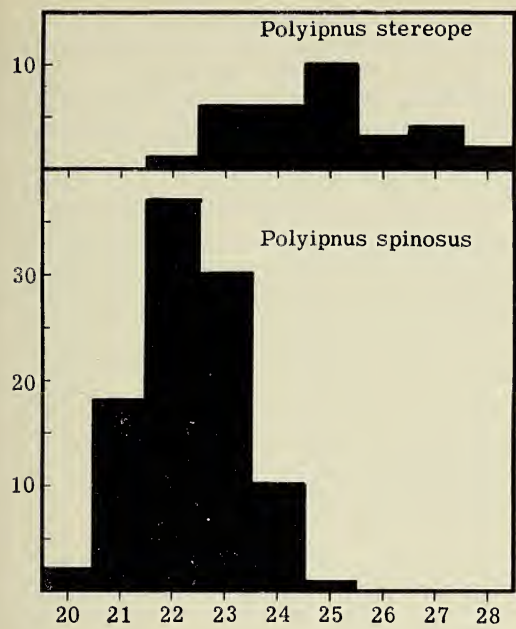


FIG. 6. Frequency of gill rakers on the first gill arch of *Polyipnus spinosus* and *P. stereope*.

The results of these analyses are summarized in Table 6.

Significant "slope differences" in the two allometric lines may be recognized in the depth at end of dorsal to body length and depth of caudal peduncle to body length but not in the depth at origin of dorsal and length of posttemporal process to body length. Furthermore, "positional differences" in the two allometric lines undoubtedly may be expected in these body parts to body length.

Meristic Characters

To indicate the differences of meristic characters between the two species more satis-

factorily, we have indicated the frequency distributions of meristic characters by histograms for each species. The two meristic characters used are:

1. Numbers of gill rakers on the first arch (Fig. 6).

In *P. spinosus* the numbers of gill rakers on the first arch are distributed from 20 to 25 and the mode of these frequencies may be recognized at 22. But in *P. stereope* the frequencies are distributed from 22 to 28 and the mode of these frequencies may be recognized at 25.

2. Numbers of pectoral fin rays (Fig. 7).

In *P. spinosus* the numbers of pectoral fin rays are distributed from 12 to 14 and the mode of these frequencies may be recognized at 13. But in *P. stereope* the frequencies are distributed from 13 to 16 and the mode may be recognized at 14.

From these observations we have found that the two species are apparently separable in four body proportional characters and two meristic characters. Therefore we conclude that *Polyipnus stereope* Jordan and Starks should be treated as a distinct species. We are unable to come to a decision as to whether *Polyipnus trigentifer* McCulloch is to be regarded as a synonym of one of these other two species or not, because we were unable to obtain Australian specimens of *Polyipnus trigentifer* McCulloch to compare with the present two species. However *Polyipnus trigentifer* McCulloch seems to differ from both of the present two species in the numbers of anal photophores, that is it has 15–17 whereas the other two species have 12–14.

TABLE 2  
"SLOPE AND POSITIONAL DIFFERENCES" BETWEEN TWO ALLOMETRIC LINES OF DEPTH  
AT ORIGIN OF DORSAL-BODY LENGTH RELATIONSHIP

RESIDUE FORM	SUM OF SQUARES	(d.f.)	(S.S./d.f.)
Separate lines . . . . .	0.02136	126	0.000170
Slope differences . . . . .	0.00016	1	0.000160
Parallel lines . . . . .	0.02125	127	F <sub>0</sub> = 0.941
Parallel lines . . . . .	0.02125	127	0.000169
Positional differences . . . . .	0.03738	1	0.037380
Single line . . . . .	0.05890	128	F <sub>0</sub> = 221.183**



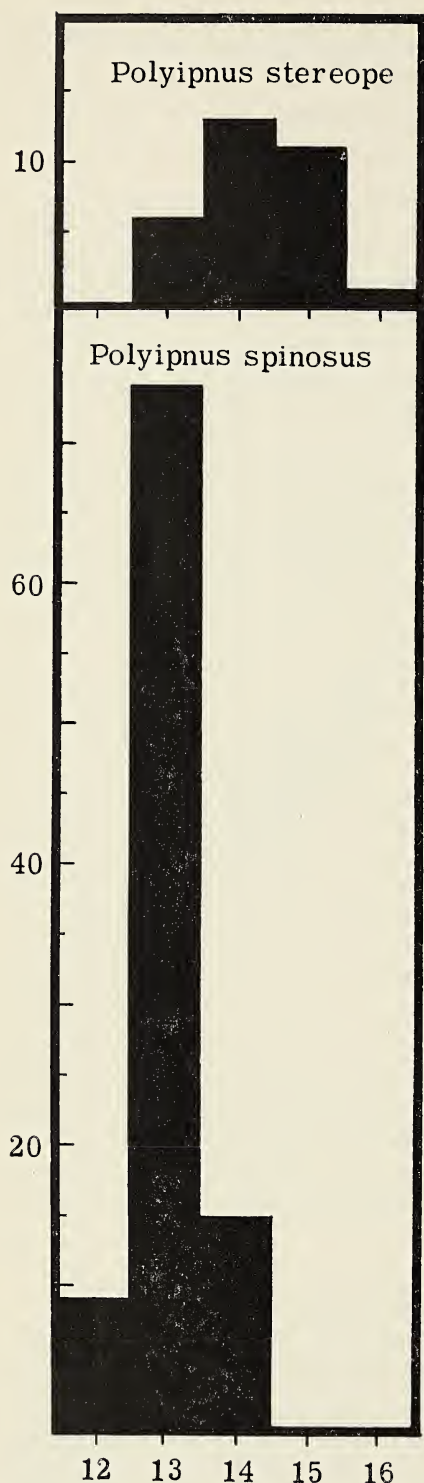


FIG. 7. Frequency of pectoral fin rays in *Polyipnus spinosus* and *P. stereope*.

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TABLE 3  
 "SLOPE AND POSITIONAL DIFFERENCES" BETWEEN TWO ALLOMETRIC LINES OF DEPTH  
 AT END OF DORSAL-BODY LENGTH RELATIONSHIP

RESIDUE FORM	SUM OF SQUARES	(d.f.)	(S.S./d.f.)
Separate lines . . . . .	0.06835	126	0.000542
Slope differences . . . . .	0.00261	1	0.002610
Parallel lines . . . . .	0.07096	127	$F_0 = 4.817^*$
Parallel lines . . . . .	0.07096	127	0.000559
Positional differences . . . . .	0.19794	1	0.197940
Single line . . . . .	0.26890	128	$F_0 = 354.097^{**}$

TABLE 4  
 "SLOPE AND POSITIONAL DIFFERENCES" BETWEEN TWO ALLOMETRIC LINES OF DEPTH  
 OF CAUDAL PEDUNCLE-BODY LENGTH RELATIONSHIP

RESIDUE FORM	SUM OF SQUARES	(d.f.)	(S.S./d.f.)
Separate lines . . . . .	0.06968	126	0.000553
Slope differences . . . . .	0.00448	1	0.004480
Parallel lines . . . . .	0.07416	127	$F_0 = 8.101^{**}$
Parallel lines . . . . .	0.07416	127	0.000584
Positional differences . . . . .	0.32115	1	0.321150
Single line . . . . .	0.39531	128	$F_0 = 549.932^{**}$

TABLE 5  
 "SLOPE AND POSITIONAL DIFFERENCES" BETWEEN TWO ALLOMETRIC LINES OF LENGTH  
 OF POSTTEMPORAL PROCESS-BODY LENGTH RELATIONSHIP

RESIDUE FORM	SUM OF SQUARES	(d.f.)	(S.S./d.f.)
Separate lines . . . . .	0.04707	126	0.000374
Slope differences . . . . .	0.00000	1	0.000000
Parallel lines . . . . .	0.04707	127	$F_0 = 0.000$
Parallel lines . . . . .	0.04707	127	0.000371
Positional differences . . . . .	0.10539	1	0.105390
Single line . . . . .	0.15246	128	$F_0 = 284.070^{**}$

TABLE 6  
 SUMMARY OF "SLOPE AND POSITIONAL DIFFERENCES" BETWEEN TWO ALLOMETRIC LINES  
 OF FOUR BODY PARTS TO BODY LENGTH

BODY PART	SLOPE DIFFERENCES	POSITIONAL DIFFERENCES
(a) Depth at origin of dorsal . . . . .	—	**
(b) Depth at end of dorsal . . . . .	*	**
(c) Depth of caudal peduncle . . . . .	**	**
(d) Length of posttemporal process . . . . .	—	**

\*\* , significant ( level of significance 1 % )

\* , significant ( level of significance 5 % )

— , insignificant



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# The Probable Method of Fertilization in Terrestrial Hermit Crabs Based on a Comparative Study of Spermatophores<sup>1</sup>

DONALD C. MATTHEWS<sup>2</sup>

ALTHOUGH the physiological and mechanical phenomena of the vasa deferentia resulting in the elaboration of the spermatophores of marine hermit crabs (Pagurida) have been investigated (Mouchet, 1931; Matthews, 1953), these phenomena in terrestrial hermit crabs (*Coenobita* and *Birgus*) have been neglected. Spermatophores of marine hermits are made with precision; the so-called immutable form of their acuminate capsules is often distinctive of the species. These capsules, "elevated" on slender stalks, are admirably adapted for aquatic dissemination of the spermatozoa. Because marine hermit crabs are regarded as the progenitors of terrestrial hermit crabs, the present study was undertaken to reveal whether the form of the aquatic spermatophore has become modified in the change to a terrestrial environment, and if so, to consider, in lieu of actual observation, whether these modifications are of sufficient magnitude to make tenable the common assumption that in terrestrial hermits fertilization occurs on land.

## METHODS AND TECHNIQUES

The method employed was to study the phenomena of spermatophore elaboration in (1) a truly aquatic hermit crab, (2) a "transi-

tional" terrestrial hermit with gastropod shell, and (3) a terrestrial hermit, no longer protected by a gastropod shell. For the typical aquatic hermit, *Dardanus punctulatus* (vide Edmondson, 1946: 265) was selected. These were taken at Oahu, Territory of Hawaii, between June, 1953, and July, 1954. *Coenobita rugosus*, the selected "transitional" hermit, and *Birgus latro*, the selected terrestrial hermit, were taken at Eniwetok Atoll (Marshall Islands) between September 1, 1954, and September 15, 1954.

The abundant *C. rugosus* were easily collected but the scarce *B. latro* had to be dug from their burrows. These hermits were killed and dissected at the Marine Laboratory at Eniwetok. There, the male reproductive systems, for purposes of routine histological examination, were placed in Bouin's fixative, cleared in toluene, embedded in Tissuemat (54°-56° C.), sectioned at 10 microns, stained with standard alum-haematoxylin and counterstained with eosin (0.5 per cent solution in 90 per cent alcohol to which 0.4 cc. of 0.1 N HCl was added). Some testis sections of both aquatic and terrestrial hermits were stained with Heidenhain's iron-haematoxylin without a counterstain, while others were stained with safranin (Grubler's "Safranin O") and counterstained with light green. Because the large, proximal portions of the vasa deferentia of both aquatic and terrestrial hermits became extremely brittle after fixation, and were sectioned only with difficulty, sim-

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ilar unfixed portions were immersed for 10–30 minutes in an aqueous solution of toluidin blue (1–10,000), teased open in sea water, and their vitally stained contents studied.

#### OBSERVATIONS

##### *Macroscopic Observation of Abdomens*

When removed from the protective gastropod shell, the soft, vulnerable abdomen of *D. punctulatus* is seen to be twisted in accordance with the clockwise helical shell. Although five tergal plates are clearly discernable, they are weakly sclerotized. Pleopods are present only on the left side. The uropods are highly modified and serve primarily as hold-fasts.

Removal of the protective gastropod shell from *C. rugosus* discloses an abdomen which approximates that of *D. punctulatus*. Again the soft abdomen is twisted in compliance with the spiral shell and although five tergal plates are present they are poorly sclerotized. As in aquatic hermits, the pleopods are present only on the left side. Again the uropods are modified for attachment.

The unprotected abdomen of *B. latro* (vide Harms, 1932: figs. 1, 2, 3, 4) is straight, stubby, and its broad tergal plates are more heavily sclerotized than either those of *D. punctulatus* or *C. rugosus*. Pleopods are again restricted to the left side. The uropods are modified and reduced but obviously serve no longer as hold-fasts.

##### *Macroscopic Observations of Dissected Abdomens*

Typical of the dissected abdomens of aquatic hermits is (Matthews, *op. cit.*, fig. 2–b, p. 257) that of *D. punctulatus* in which a large, paired, hepatopancreas almost fills the entire abdominal cavity. The hepatopancreas, because of connecting mesenteries, carries the testes and vasa deferentia as it follows the turns of the abdomen and is largely responsible for the asymmetrical visceral arrangement. As in other aquatic hermits which inhabit

right-handed shells, the right testis and right vas deferens are crowded and somewhat reduced.

The dissected abdomen of *C. rugosus* is almost identical with that of *D. punctulatus*. Again the large hepatopancreas almost fills the abdomen and carries with it the crowded testes and vasa deferentia and again this results in the reduction of the right testis and right vas deferens.

The dissected abdomen of *B. latro* reveals a large hepatopancreas joined to the other viscera by mesenteries. The testes and vasa deferentia are neatly fitted between the right and left portions of the hepatopancreas. Slight differences in size of testis and vas deferens are observed, but the smaller occurs on the right or left side indiscriminately.

The living vasa deferentia of *D. punctulatus*, *C. rugosus*, and *B. latro* exhibit spasmodic, muscular contractions (vide Matthews, 1953: 258). However, the opacity of the vasa deferentia prevents the actual observation of the effects of these contractions on the pliable sperm mass. But, as will be shown subsequently, these contractions serve both to move the sperm mass along and to mold it in compliance with gradual changes in the conformation of the vasa deferentia.

##### *Microscopic Examination of Sectioned Testes*

The sectioned testis of *D. punctulatus* is a highly coiled, continuous, thin-walled tube into which numerous sacculi open (vide Matthews, 1953: 258, fig. 3). The sacculi in cross section are observed in all stages of maturity. The immature sacculus is filled with large primary spermatocytes; others, more mature, are filled with spermatids in all stages of metamorphosis. These are expelled from the sacculus into a minute collecting tubule of the testis by the proliferation of new primary spermatocytes from the germinal epithelium of each sacculus. In other words, the old metamorphosing spermatids are crowded or pushed out of the sacculus by the development of new primary spermatocytes. The

study of many sacculi reveals this to be a rhythmical process. This process produces a continuous sperm mass. This undifferentiated sperm mass enters the small, proximal vas deferens (*vide* Matthews, 1953: 259, fig. 6).

Fundamentally, the sectioned testis of *C. rugosus* resembles that of *D. punctulatus*. The sacculi open into a minute, highly coiled collecting tubule. Sacculi are seen in all stages of maturity. Except for slight differences of detail, the process of filling the sacculi with primary spermatocytes and the expulsion of metamorphosing spermatids is identical with that of *D. punctulatus*. Again the combined, rhythmical, saccular activity provides a continuous, undifferentiated sperm mass which enters the proximal portion of the vas deferens.

The sectioned testis of *B. latro* resembles those of *D. punctulatus* and *C. rugosus*. Sacculi in all stages of maturity are observed and again their rhythmical activity fills the minute collecting tubule with metamorphosing spermatids. The differences observed are primarily of size, the sacculi of *D. punctulatus* and *C. rugosus* being generally smaller than those of *B. latro*. Also observed were slight differences in the number and arrangement of sustentacular cells (*vide* Matthews, 1954: 116, fig. 2b). Although these were present in all sacculi whose spermatids were metamorphosing, their fate still remains obscure.

#### *Microscopic Examination of Sectioned Vasa Deferentia*

Cross sections through the proximal portion of the vas deferens of *D. punctulatus* reveal a minute cylindrical tube with a thin wall of contractile tissue and cuboidal epithelium, the almost circular lumen of which is completely occupied by a discoidal portion of the continuous, rod-shaped sperm mass (*vide* Matthews, 1953: 259, fig. 6). Except for slight differences in size, comparable portions of the proximal vasa deferentia of *C. rugosus* and *B. latro* appear identical with those of *D. punctulatus*.

In *D. punctulatus*, as the vas deferens gradually increases in diameter the once circular lumen becomes ellipsoidal (*vide* Matthews, 1953: 260, fig. 7). This change in shape of the lumen is the result of the bounding epithelial cells which have become columnar except at the more pointed extremities of the lumen where cuboidal epithelium still persists. An acidophylic secretion from these cuboidal cells lines the lumen but later surrounds and adheres to the sperm mass to form the thin, sperm mass sheath (*vide* Matthews, 1953: 261, fig. 9). In compliance with the change in shape of the lumen, the sheathed sperm mass becomes ellipsoidal. In *C. rugosus* and *B. latro* cross sections through comparable regions of the vas deferens also reveal ellipsoidal lumina and sheathed sperm masses.

In *D. punctulatus*, cross sections of the vas deferens reveal that the ellipsoidal lumen gradually becomes pear-shaped and that the sheathed sperm mass becomes folded into arches (*vide* Matthews, 1953: 262, fig. 10). A new secretion arises from the epithelial cells at the more pointed end of the lumen; this secretion fills the spaces between the closing arches and forms the "upright" stalks (*vide* Matthews, 1953: 262–263, figs. 11, 12, 13). As this secretion accumulates, the stalks lengthen and the ampullae of sperm are carried "aloft."

In *C. rugosus* and *B. latro* a similar change from an ellipsoidal to a pear-shaped lumen is observed and, accompanying this change, the contained, sheathed, sperm mass is folded into arches. In like manner a secretion, arising from epithelial cells of the pointed end of the lumen, fills the spaces between the closing arches and forms the "upright" stalks. Again, as this secretion accumulates, the stalks lengthen and "elevate" the closing arches to form the ampullae of sperm.

In *D. punctulatus*, *C. rugosus*, and *B. latro* (Fig. 1a–c) still another secretion is given off by the epithelial cells (*ep.*) bordering the lumen which surrounds the "upright" stalks (*st.*) and ampullae (*am.*) and forms the veil



(v.). In *D. punctulatus* the groove of the lumen is deep and results in the formation of tall, thin spermatophores (Fig. 1a). In *C. rugosus* (Fig. 1b) and *B. latro* (Fig. 1c), the groove is shallow and results in the formation of short, broad spermatophores.

#### DISCUSSION

The spermatophores of *D. punctulatus*, *C. rugosus*, and *B. latro* are formed with great precision. The spermatophores of any one *D. punctulatus* are similar to those of any other of its species. In like manner, the spermatophores of *C. rugosus* and *B. latro* do not vary within the species. However, only in this restricted sense is it permissible to refer to the spermatophores of any one species as being immutable. Because immutable precludes change, its use in connection with spermatophores is untenable. What is probably meant by the use of this term is that, for any one species at the time of observation, spermatophores appear identical. Surely, the complicated mechanical and physiological phenomena associated with spermatophoric development have evolved throughout the ages and these changes have been accompanied by changes in spermatophores.

Although in *D. punctulatus* the actual process of copulation has not been observed, there is little doubt that it occurs in water. This species does not frequent the shallow reef waters and, so far as is known, never comes ashore even at night. Specimens taken in fishermen's nets frequently show spermatophores attached to both body and gastropod shell. This same attachment of spermatophores is also observed in this species at the Honolulu Aquarium where, prior to spermatophoric deposition, males are frequently seen dragging females about. However, since copulation probably takes place at night, it has not been possible to observe the process in these captive specimens. Moreover, as these specimens are afforded no opportunity to leave the tanks, copulation and the subsequent process

of fertilization must occur in water. Therefore, the possibility of terrestrial copulation and fertilization in free living specimens remains but seems rather unlikely.

The spermatophores of *C. rugosus* (Fig. 2b) resemble closely the spermatophores of *D. punctulatus* (Fig. 2a). There are obvious differences in size of ampullae, upright stalks, veil, etc., but the fundamental plan is the same. This fact, coupled with similarities of spermatophoric development, strongly suggests that for this species the rate and extent of adaptive changes in the reproductive system did not parallel the rate and extent of other terrestrial adaptations. The similarity of these spermatophores with those of *D. punctulatus* should not be interpreted as due to the immutability of *C. rugosus* spermatophores, but rather, that at the particular time of observation, the spermatophores of *C. rugosus* had not "progressed" beyond the aquatic spermatophore level attained by *D. punctulatus*.

Again, copulation and the subsequent process of fertilization in *C. rugosus* have not, to the author's knowledge, been recorded. Even though *C. rugosus* in certain of its organ systems is admirably adapted for a terrestrial habitat, caution should be exercised in assuming that all organ systems are equally so adapted. The literature is replete with reference to the female's dependence on the sea. Harms (1932: 260 [translated]) states:

The East Indian "Coenobites" seem to spawn all year long, but they seem to reach a climax in the months of January to March. During those months I observed how flocks of *Coenobita cavipes* and [*C.*] *clupeatus* wandered during the night toward the coast of Perbaengan (East coast of Sumatra) in order to deposit their zoëa into the water. At the end of May till the beginning of July I observed how the beach swarmed with "Coenobites" in all phases of metamorphosis. . . . On the the island of Siberoet I saw the same thing between May 31 to June 5, 1929, but here *Coenobita rugosus* were involved. The young "Coenobites" emerge from the water with tiny snail-shells, and live at first amphibiously.

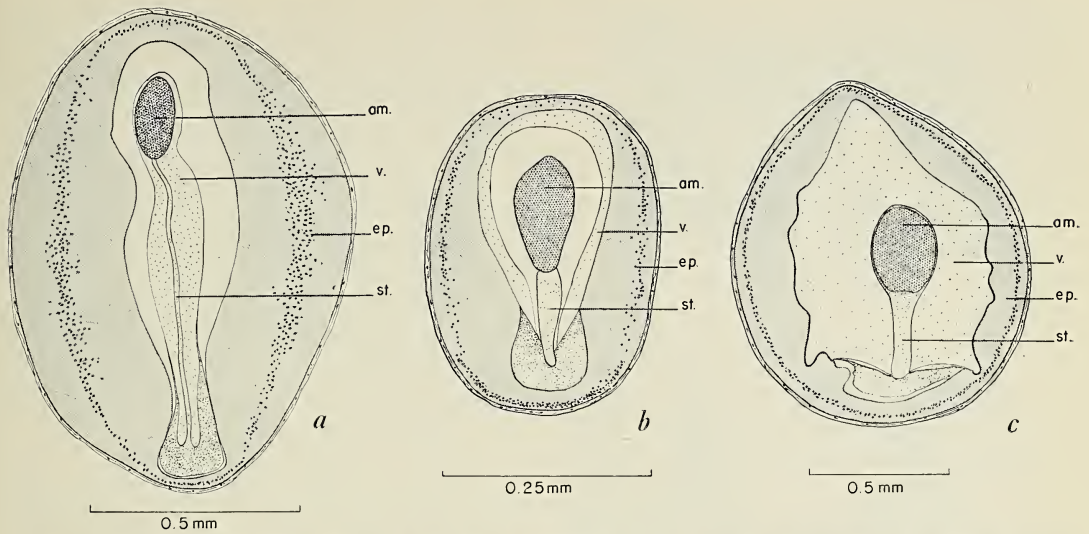


FIG. 1. Diagrammatic cross section of the vas deferens of: *a*, *Dardanus punctulatus*; *b*, *Coenobita rugosus*; *c*, *Birgus latro* showing: *am.*, ampulla; *v.*, veil; *ep.*, veil-producing epithelium; *st.*, stalk.

Again in reference to "Coenobites" dependence on the sea, Dr. Yoshio Kondo, terrestrial malacologist of the Bernice P. Bishop Museum, informs me (*in litt.*) that on Saipan swarms of these land crabs make monthly, full-moon migrations to the sea. At this time they are gathered by the bushels for food and, so far as is known, both males and females are taken. The possibility therefore exists that these nocturnal migrations may serve purposes other than the moistening of the gills or the deposition of zoëa.

At Eniwetok I observed both male and female *C. rugosus* on the beach at night although I did not observe any in the water or in the act of copulation. Because females are observed with spermatophores both on their bodies and on their gastropod shells, and because the tubelike extensions on the coxopodite of the fifth pereopods are too large to serve as penes, it appears quite unlikely that an internal deposition of spermatophores takes place. Both the origin and the aquatic form of *C. rugosus* spermatophores suggest that copulation and fertilization occur in water.

The spermatophores of *B. latro* (Fig. 2*c*)

resemble closely the spermatophores of *D. punctulatus* (Fig. 2*a*) and *C. rugosus* (Fig. 2*b*). There are obvious differences in size of ampullae, upright stalks, veils, etc., but again, the fundamental plan is the paguridan aquatic spermatophore. As in *C. rugosus*, this fact, coupled with the similarity of their spermatophoric development, strongly suggests that in *B. latro* also the rate and extent of reproductive adaptations did not parallel the rate and extent of other adaptations. Again, this is not an example of the immutability of spermatophores but rather, at the time of observation, the spermatophores of *B. latro* had not "progressed" beyond the level of the aquatic spermatophore attained by *D. punctulatus*.

Harms (*op. cit.*: 262 [translated]) in reporting on the reproductive activity in *B. latro* says:

The process of copulation is at this time still unknown. The males do not have special organs for copulation. Yet copulation must take place, and seems to do so on land, since females are found at great distance from the coast. The sperms are probably transmitted by means of spermatophores. In response to excitation I got the male to emit masses of sperm [spermatophores]. These hardened subsequently. . . .



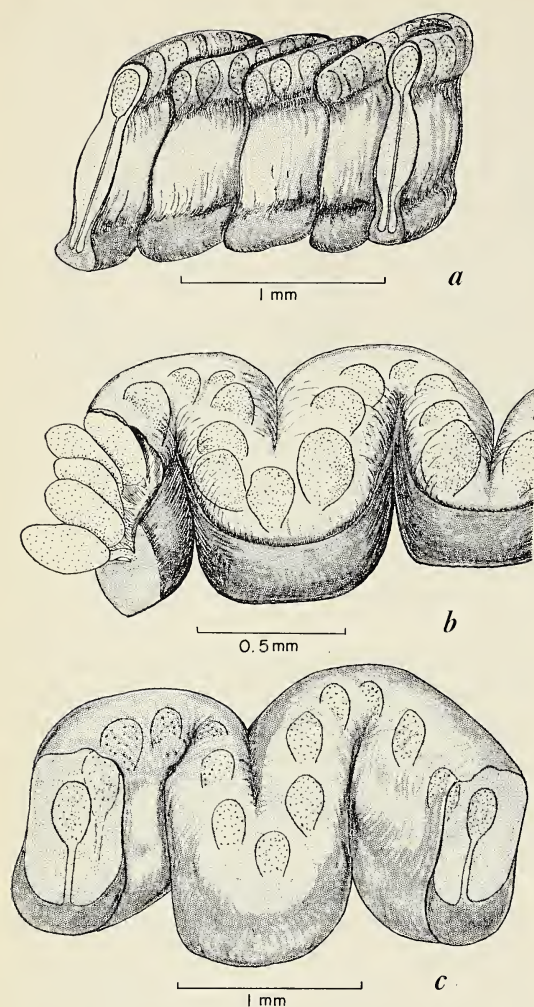


FIG. 2. Portion of vitally stained spermatophore of: a, *Dardanus punctulatus*; b, *Coenobita rugosus*; c, *Birgus latro*.

The possibility exists that these gummed up masses of sperm are transferred to the female . . . the development inside the egg goes as far as the zoëa, which has been described by Borradaile [1900]. . . . *Birgus* has a typical paguride zoëa, which resembles on the whole the zoëas of *Spiropagurus* and of *Eupagurus*. . . . The peculiarity of the zoëas of *Birgus* lies in a certain simplification of its over-all organization, illustrated especially by the absence of otherwise typical bristles and teeth. Perhaps it can be assumed with certain confidence that further development up to the metamorphosis takes place exactly as with the rest of the pagurids, especially the "Coenobites."

Harms (1937: 14) further states that the eggs are fertilized at the place of deposit and become attached immediately. He does not say however, how or where this process takes place.

According to the observations of Andrews (1900) on Christmas Island, *B. latro*, too, like the "Coenobites" wanders in great flocks to the sea in the months of January to March. Presumably both males and females take part in these migrations and the possibility exists that in this case, as with *C. rugosus*, the purpose might be for copulation as well as the deposition of zoëa.

At Bikini in July 1947 Dr. Robert Hiatt observed numerous zoëa in the water in which a berried female had been contained overnight. He also observed berried females with their abdomens immersed in intertidal pools liberating zoëa.

Because this part of the reproductive cycle of *B. latro* requires an aquatic environment it appears likely that the liberation of sperm from the spermatophore and fertilization are aquatic. This would not obviate the possibility of a terrestrial attachment of the spermatophore. However, the similarity in the development of spermatophores in the "terrestrial" *C. rugosus* and *B. latro* and in the truly aquatic *D. punctulatus*, seems to argue for the assumption that copulation and the subsequent process of fertilization are also aquatic in these terrestrial species. Surely, this assumption is more valid than the assumption that for these species fertilization takes place on land, "since females are found at great distance from the coast." Without attempting to explain what has brought about modifications for a terrestrial existence, modifications of the reproductive system are not as urgent as, for example, those of the respiratory system which must be used continuously once emergence has occurred. Reproduction, although obviously important to maintain the species, is not a continuous process, therefore, not of primary urgency for the survival of the individual. When necessary, the crabs can return

to their old habitat, water, as do the Amphibians.

In lieu of actual observation to the contrary the modifications of the spermatophores of *C. rugosus* and *B. latro* are not of sufficient magnitude to make tenable the common assumption that terrestrial hermit crabs are fertilized on land. Stationed at a likely spot, a patient observer, equipped with an infra-red light, may provide the ultimate solution to this problem by direct observation of copulation and fertilization in terrestrial hermit crabs.

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## Two New Fleas (Siphonaptera: Rhadinopsyllinae) from Japan

KÔHEI SAKAGUTI and E. W. JAMESON, JR.<sup>1</sup>

RECENT COLLECTIONS have added two unnamed fleas to the fauna of Japan. Both species are in the subfamily Rhadinopsyllinae; one belongs to the genus *Rhadinopsylla* Jordan and Rothschild and the other is a species of the closely allied genus *Stenischia* Jordan. Attention is called to the recent discussion by Morland and Prince (1954: 1037) on the status of *Rhadinopsylla* and several of its subgenera; they place *Rectofrontia* Wagner as a subgenus of *Rhadinopsylla*, a combination we shall continue to use. Previously Hopkins (1952: 365) placed *Rangulopsylla* Darskaya as a synonym of *Rectofrontia*.

Heretofore *Rhadinopsylla* (*Rectofrontia*) *attenuata* Jameson and Sakaguti has been the only species of Rhadinopsyllinae known from Japan. The two species described in this paper bring this number to three. A fourth species, *Rhadinopsylla* (*Rectofrontia*) *fraterna* ssp., was taken by the senior author from the mouse, *Apodemus geisha*, at Kamikochi in Nagano-Ken (1,500 meters, elevation) 3 December 1952. Several species of *Rhadinopsylla* which are known from the adjacent Asiatic mainland are unknown in Japan. More of these interesting fleas may be found if collectors examine the nests of small mammals.

*Rhadinopsylla* (*Rectofrontia*) *japonica* n. sp.  
Fig. 1

MALE: Head (Fig. 1a) with an acute frontal tubercle and five genal teeth; the uppermost genal tooth is two times as wide as the adjacent tooth and overlaps it at its base. There are two rows of preantennal and three rows of postantennal (occipital) setae. A clear ocular area at the base of the uppermost genal spine. Labial palpus five-segmented, not quite reaching the tip of the fore-coxa.

Pronotum (Fig. 1a) with six or seven spines per side. Mesonotum (Fig. 1b) with three rows of setae as shown, and with two pseudosetae per side, under the collar. Metanotum with two rows of setae.

Coxa III with a mesal patch of setae. Fifth tarsal segment of each leg with four pairs of lateral plantar bristles.

Each abdominal tergite with a row of alternating long and short setae; abdominal terga I-V each with a small anterior row, and with two to four marginal teeth, placed dorsally. Abdominal sternites each with two or three long setae ventrally.

Fixed process of clasper (Fig. 1c) entire, with one long seta laterally near the dorsal margin, and several (six to eight) small setae on the dorsal margin. Moveable finger not extending to the dorsal margin of the clasper. Sternite VIII rudimentary. Sternite IX (Fig.

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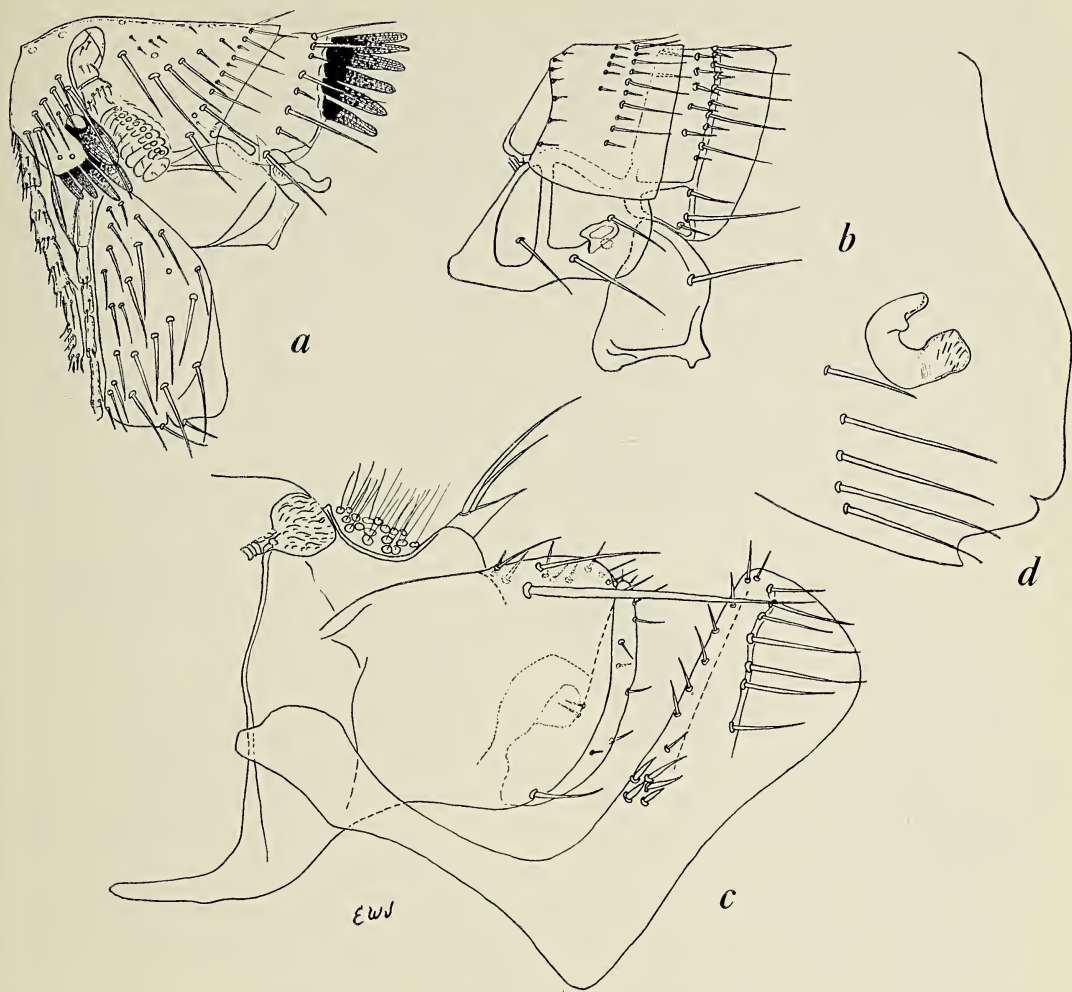


FIG. 1. *Rhadinopsylla* (*Rectofrontia*) *japonica*, new species: *a*, head and prothorax of male; *b*, meso- and meta-thorax of male; *c*, sternite IX, movable finger, and fixed process of clasper; *d*, sternite VII and seminal receptacle of female.

1c) expanded distally; characteristic and unique is the cluster of five or six thick, short setae near the base of the distal arm.

**FEMALE:** In general similar to male. Chaetotaxy of head as in male. Two antepygial bristles per side. Sternite VII (Fig. 1*d*) with a sharp incision and a shallow sinus on the ventral margin. Body of seminal receptacle slightly enlarged caudally, the neck gradually narrower than the body; neck with a caudal projection.

**TYPES:** Holotype male and allotype female from the flying squirrel, *Petaurista leucogenys oreas* Thomas, Mt. Kurama, Kyoto-Fu, Honshu, Japan; 2 Nov. 1952; coll. Kôhei Sakaguti and deposited in the collection of Kôhei Sakaguti. Paratypes with same data as types, 2 Nov. 1952 and from the same host; Kibune, Kyoto-Fu, Honshu, Japan; 10 Jan. 1954; coll. Kosaburo Torii. Paratypes deposited at the British Museum (at Tring) and in the collections of the authors.



REMARKS: This new species resembles *R. pentacanthus* (Rothschild), but the uppermost genal tooth is even more enlarged. The first occipital row of setae is markedly reduced in this new species, and it is unique in the thick setae near the base of sternite IX.

The genus *Stenischia* has been known heretofore only from one female from Szechuan, China. In a recent letter, Mr. Smit of the British Museum wrote that this flea (*Stenischia mirabilis* Jordan) has not since been collected. This second collection of *Stenischia* is from Mt. Fuji, and also consists of but a single female. The Mt. Fuji specimen differs in several respects from *S. mirabilis* and represents an additional species of this genus.

*Stenischia fujisania* n. sp.

Fig. 2

FEMALE: Head (Fig. 2a) with five genal teeth; the uppermost quite small, and overlapping the adjacent genal tooth at its base. The remaining four genal teeth twice as wide and twice as long as the uppermost tooth. Chaetotaxy as illustrated. Labial palpus five-segmented, extending to the apex of the fore-coxa. A narrow, transparent ocular area.

Pronotum (Fig. 2a) with seven pigmented teeth per side. Mesonotum (Fig. 2b) with a row of four moderately long setae near the caudal margin, and with two pseudosetae under the collar. Metanotum with a strongly

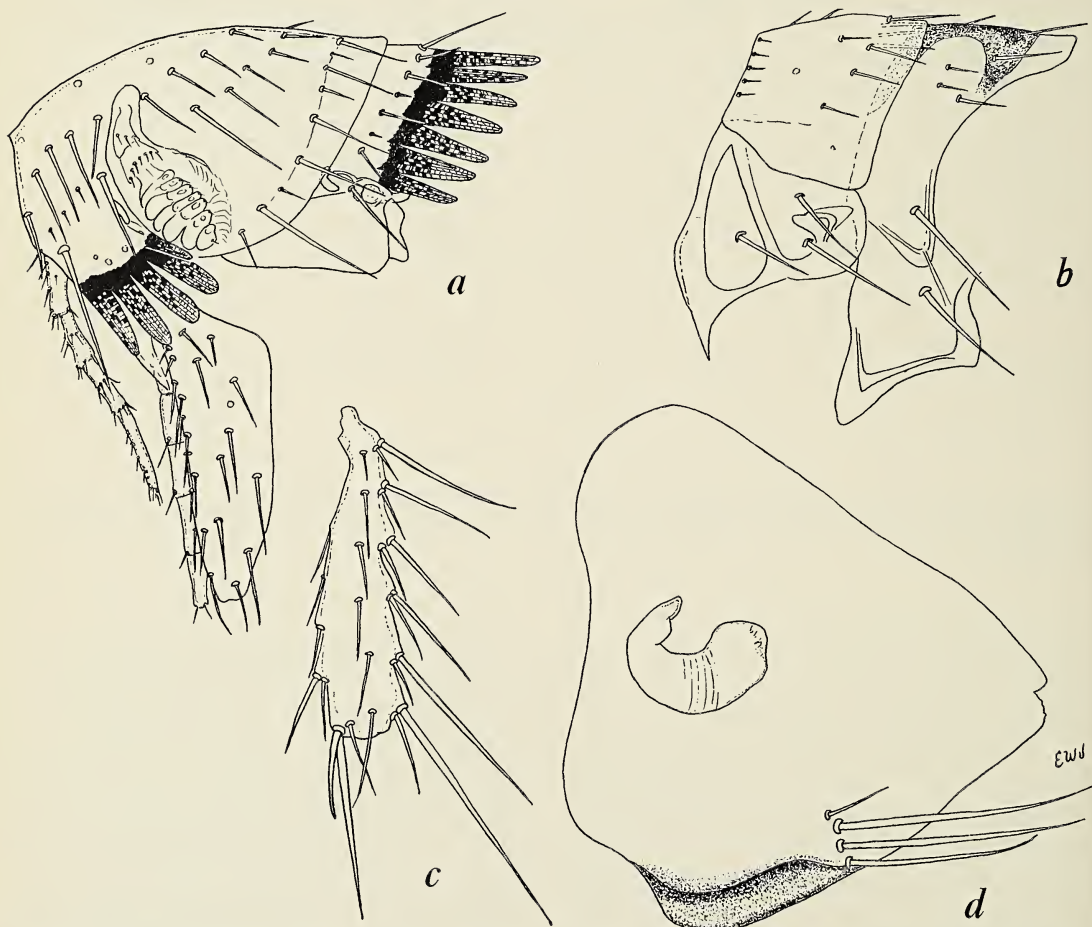


FIG. 2. *Stenischia fujisania*, new species: a, head and prothorax of female; b, meso- and metathorax of female; c, hind tibia of female; d, sternite VII and seminal receptacle of female.

sclerotized area dorsally; with two rows of setae on the dorsal half, and a long seta near the ventral margin. Episternum of metathorax fused with metepimerum.

Coxa III with a mesal patch of about thirty fine setae. Setae of hind tibia long (Fig. 2c), the long seta at the apex as long as the first tarsal segment. Fifth tarsal segments of the first and second legs each with four lateral plantar bristles; this segment of the third legs is missing in the holotype.

Each abdominal tergite with a row of one to five long setae, separated by smaller setae; on abdominal tergum I is an additional row of small setae anteriorly. Each terga with two or three apical spines, near the dorsal margin. Three antepygidial bristles per side, between which is a caudal extension (from tergum VII) bearing two teeth. Below the antepygidial bristles the margin of tergum VII projects as an acute point. Terga and sterna with dark sclerotized areas (Fig. 2d).

Body of seminal receptacle (Fig. 2d) evenly rounded, truncate ventrally at the tip. Neck with a caudal swelling. Sternite VII with a small but distinct cleft.

TYPE: Holotype female from *Mustela* sp.; Mt. Fuji, Shizuoka-Ken, Honshu, Japan; 10 July 1954; coll. L. W. Teller. Deposited in the

United States National Museum.

REMARKS: *Stenischia fujisania*, n. sp., differs from *S. mirabilis*, the genotype and only other species in the genus, in several features. In *mirabilis* the genal teeth are distinctly separate at their bases but touching in *S. fujisania*. The setae of the tibiae are conspicuous in the new species, and the seminal receptacle is much larger than that of *mirabilis*. In *S. fujisania* there is a distinct cleft or sinus on the margin of sternite VII which is absent in *S. mirabilis*.

It is a pleasure once again to acknowledge the aid we have received from Mr. F. G. A. M. Smit in preparing these descriptions. We are also grateful to Mr. L. W. Teller for allowing us to name the species of *Stenischia* from Mt. Fuji.

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## Clasping Mechanism of the Cottid Fish *Oligocottus snyderi* Greeley

ROBERT W. MORRIS<sup>1</sup>

*Oligocottus snyderi* is a small, tide-pool fish found along part of the Pacific coast of North America. The male of this species has a well-developed penis and fertilization is internal. I studied its breeding and spawning habits under laboratory conditions during a number of years. Copulation was observed on many occasions. No definite patterns of display or courtship activities were apparent and copulation took place in an atmosphere of carefree promiscuity. Such behavior may not be normal, however, for under the conditions of these observations the fish were crowded and subject to the numerous artificialities of laboratory life.

In this species the first two rays of the anal fin of the male are set apart and the first one is much larger and longer than the others of the series (see Fig. 2*a*). This first enlarged ray is prehensile and during copulation it is bent anterolaterally around the female. The lateral curvature of the ray can be directed to either the right or left, permitting the male to seize the female from either side. Copulation takes place away from solid substrate and the embrace may last for as long as 4 or 5 seconds. The strength of the ray's grasp is sufficient to hold the male and female together as they whirl about vigorously (see Fig. 1).

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### ANATOMY

Terminology of the following account is adapted from Starks (1901) and Green and Green (1915).

Figure 2*b* shows the appearance of the male fish after removal of the skin and with the lateral inclinator muscles of the unmodified rays shaded. Each inclinator originates on a myocomma and passes posteriorly across two segments to insert on the side of the head of its ray. Superficially no inclinators are visible on the first two rays.

After removal of the myotomes, the deep muscles associated with the anal fin appear as shown in Figure 3*a*. A section of the peritoneum (bordered by crosshatching) shows how the anal fin mechanism has advanced and reduced the posterior limit of the coelom to a concavity. Discussion of the muscles is deferred until after consideration of the skeleton.

The first three interhemal bones and ossicles are greatly modified as shown in Figure 3*b*. The first interhemal rests on the ossicle at the base of the first ray and arches posteriorly at its dorsal extremity. For its entire length it bears a prominent crest on each side. These crests terminate in broad lateral expansions proximal to the head of the first ray as shown in Figure 4*a*. The second interhemal likewise rests on the first ossicle but also articulates posteriorly with the second. The first ossicle is a doubled bone and in



FIG. 1. Approximate positions of the male and female during copulation (male in heavy outline; female stippled outline).

lateral aspect is L shaped. The second ossicle appears to be single and is slightly concave on its dorsal side. The third interhemal articulates with the second and third ossicles. In some specimens the second interhemal has two crests on each side and in others only a single, branched crest as shown in Figure 3*b*. The third interhemal has a single crest on each side.

The left parapophysis of the eleventh vertebra is indicated in stippled outline in Figure 3*b*. The posterodorsal end of the first interhemal is firmly attached to both parapophyses of the eleventh vertebra near the centrum by short, heavy ligaments (see Fig. 4*a*). These parapophyses are in turn firmly anchored to a myocomma and to the transverse septum. Their proximal ends are hooked as shown in Figure 4*b*. I am unable to attach any particular significance to this hook.

The hemirays making up the first ray are held together loosely by connective tissue except at the distal end where they are fused for a length of about 3 or 4 mm. (see Figure 4*a*). This condition permits a degree of independent movement of the hemirays along the long axis. Figure 4*c* shows the first three interhemals and ossicles, and the first two anal rays, the latter with the left hemirays intact. A small hook on the head of the first hemiray turns medially over the dorsal surface of the first ossicle. The heads of the second hemirays are deeply excavate medially and almost completely cover the second ossicle.

Referring again to the muscles shown in Figure 3*a*, the most anterior of the series is

seen to originate above the crest of the first interhemal and is inserted on the anterior surfaces of the head of the first ray. This is the erector and is greatly enlarged. The second muscle originates below the crest along the blade of the first interhemal and some of its fibers originate on the second interhemal, in front of the crest(s). Its insertion is over the middle portion of the head of the first hemiray. This muscle appears to be a modified inclinator. The third muscle of the series is a rather narrow one which originates along the middle of the blade of the second interhemal and is inserted on the posterior surfaces of the head of the first ray. It is the depressor. All three of these pairs of muscles are thick

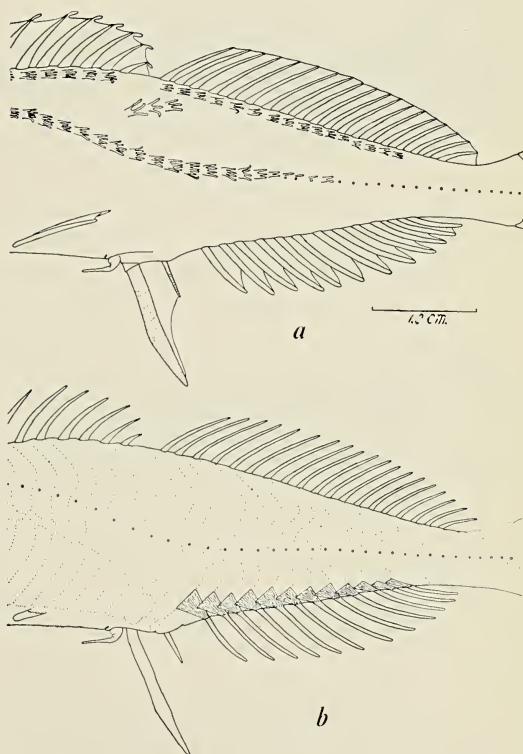


FIG. 2. *a*, Lateral aspect of a portion of the trunk and tail of the male *Oligocottus snyderi*. Protruding from the ventral profile, in left-to-right order are the: Penis, first (enlarged) anal ray, second anal ray, series of 12 unmodified anal rays. *b*, Appearance of superficial musculature after removal of the skin of the trunk and tail. Inclinator muscles of the unmodified anal rays are shaded.



and as a unit they form a subspherical mass.

I could make no distinction between any of the muscles forming the complex inserting on the head of the second ray. The elevator, inclinor, and depressor form a thick, nearly hemispherical mass on each side. This complex originates over the posterior half of the second interhemal blade and the anterior half of the blade of the third.

The erector of the third (first unmodified) ray originates on the posterior surfaces of the third interhemal and inserts on the anterior surfaces of the head of the ray. Its depressor originates on the anterior faces of the fourth interhemal and inserts on the posterior sur-

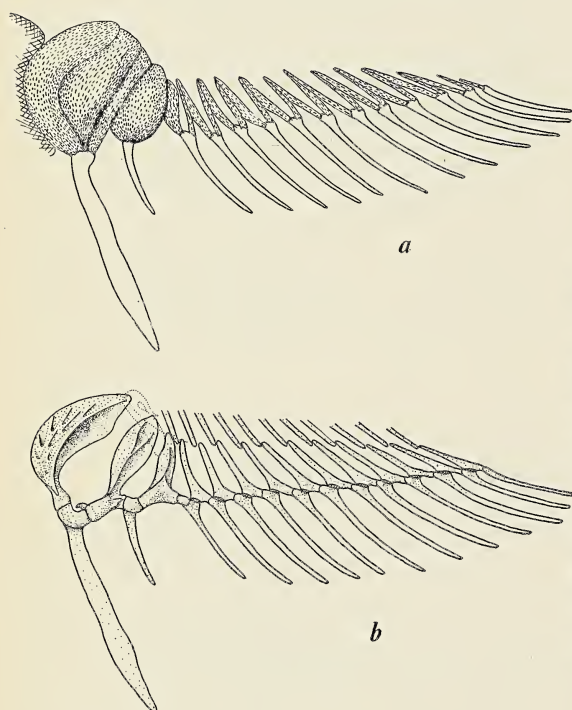


FIG. 3. *a*, Deep musculature of the anal fin. The posterior profile of the body cavity is crosshatched. In left-to-right order the muscles are: Elevator of the first anal ray, inclinor of the first anal ray, depressor of the first anal ray, muscle complex of the second anal ray, elevator of the third anal ray, depressor of the third anal ray, elevators and depressors serially repeated. *b*, Skeleton of the anal fin (with left hemirays removed). Position of left parapophysis of the eleventh vertebra is shown in stippled outline. Ends of the hemal spines of vertebrae 12 to 22, inclusive, are also shown.

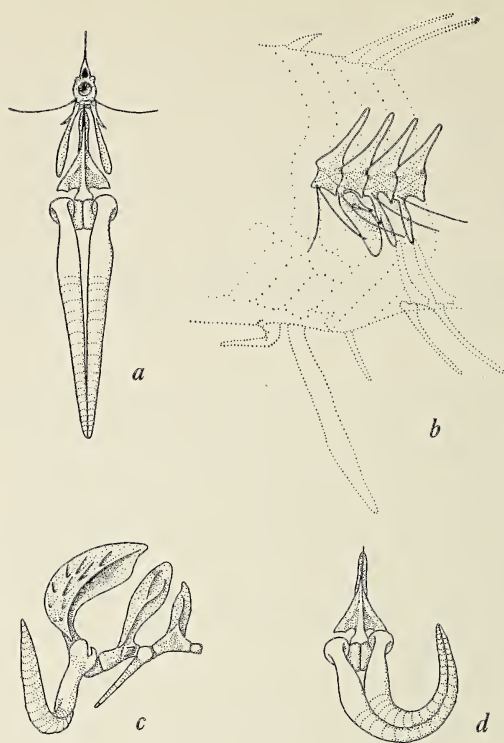


FIG. 4. *a*, Anteroventral aspect of the skeleton of the first anal ray (clasper) and the eleventh vertebra. Note the ligaments connecting the parapophyses of the vertebra with the first interhemal. *b*, Lateral aspect of vertebrae 10 to 13, inclusive. *c*, Lateral aspect of the first three interhemals and ossicles and the first two anal rays with the first ray in a partially flexed position. *d*, Anteroventral aspect of the first interhemal, ossicle, and anal ray with the latter in a flexed position.

faces of the head. As shown in Figure 3*a* the erectors and depressors diminish in size posteriorly and on the last ray I could find only a very small erector and no depressor.

#### FUNCTION

The clasper appears to be flexed in response to either visual or touch stimuli.

Flexion results from the following muscular activities. The first pair of erectors draw the first ray ahead so that it extends from the venter slightly anterior to the perpendicular. The ligaments from the first interhemal to the parapophyses of the eleventh vertebra help

hold the interhemal in position against this action.

The first inclinator of one side (the left for purposes of this description) contracts, drawing the blades of the first and second interhemals closer together. This action retracts the left hemiray, shortening the left side and causing the ray to bend in that direction. The medially directed hook on the head of the right hemiray engages over the first ossicle and prevents that side from being disarticulated.

During flexion, the depressors of the first ray are at rest.

The muscle complex on both right and left sides of the second ray appears to function as a single unit. During flexion of the first ray, this complex contracts, drawing the blades of the second and third interhemals together, thus stabilizing the second interhemal by opposing the action of the first inclinator.

The erector of the third (first unmodified) ray originates on the posterior surfaces of the blade of the third interhemal and inserts on the anterior surfaces of the head of the ray. Its contraction erects the third ray and stabilizes the third interhemal, opposing the action of the muscle complex of the second ray.

#### CONCLUSION

There are numerous accounts dealing with

modification of elements of the anal fin to form a gonopodium (see Rosen and Gordon, 1953), however, specialization of this fin as a clasping mechanism has not to my knowledge been reported among bony fishes.

Except for the "invasion" of the trunk region by the bones of the anal fin, evolution of the clasper described in this paper seems to be a rather uncomplicated matter.

From the description presented above, it can be seen that the greater the size of the male with respect to that of the female, the more effectively the clasper aids in copulation. It is interesting to consider the extent to which the trend of evolution of this species might be influenced by such a mechanism.

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# Contributions to the Knowledge of the Alpheid Shrimp of the Pacific Ocean

## Part I. Collections from the Mariana Archipelago<sup>1</sup>

ALBERT H. BANNER<sup>2</sup>

THIS IS THE FIRST of a planned series of papers on the distribution in the Pacific of the shrimp of the family Alpheidae (previously Crangonidae; name of the family and of the type genus, *Crangon*, changed by action of the International Commission for Zoological Nomenclature in February 1955, Opinion 334). A large series of collections has been made available to me. The collections were taken over a broad sweep of the Pacific, from the Tuamotus in the east to the Marianas in the west and I have supplemented these by personal collections. The series of publications will consider the collections archipelago by archipelago, and I hope to conclude them by a summarizing paper giving all citations to published works dealing with the Indo-Pacific species and full records of distribution for each species.

This work has been undertaken in the hope that these shrimp, the most common on the reefs, the most easily collected and preserved, may prove to be of value as zoogeographical and ecological "indicator organisms." Such indicator species could be used as they are used in plankton analyses to characterize and recognize certain ecological groupings correlated with the physical environment. At this

early stage it is not known whether these species will prove of value in this respect.

Inasmuch as the concluding paper will carry all bibliographic citations to previous work in the Pacific, the individual papers will carry references only to the original descriptions of the species and to other papers used in the identification of the species.

The measurements used and the names of the ridges and grooves of the large chela in the genus *Alpheus* are the same as in my paper on the snapping shrimp of Hawaii (1953: 4, 59).

### COLLECTIONS AVAILABLE

There are two major collections available from Saipan. The first I made while I was stationed there in the United States Army Air Force during the years 1944 and 1945. Unfortunately, world wars do not lend themselves well to biological collecting, and I was fortunate to be able to obtain as many specimens as I did. Perhaps half of the specimens I collected, together with all of my field notes on the localities and environments of the collections, were lost. As a consequence, I cannot assign the species to more than the general locality of Saipan. Most of my collections were made on the beach and narrow fringing reef called Unai Obyan; a few were made in various parts of the broad lagoon west of the island; none were made in Bahai

<sup>1</sup> Contribution No. 79, Hawaii Marine Laboratory. Manuscript received September 12, 1955.

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Laulau or on the north and east sides of the island because those areas were largely "out-of-bounds" with guerrilla action still taking place. The only station which I can positively identify is that for the collection dated 25 December 1944. It was made on the eastern side of the fringing reef before our camp, close to Cape Naftan; the water was about 3 feet deep within the "lagoon" of the fringing reef, the bottom was largely sand and extending above the water level were large boulders, upon the lower parts of which living coral was growing. This is the type locality for two new subspecies.

The other collection was made by Dr. Preston E. Cloud, Jr. and his party during the course of a geological survey of Saipan and is in the United States National Museum. Fortunately, there are thorough notes on the habitats of these specimens. The localities of the stations are shown in Figure 1; information on the habitats is given below:

A-5—1 mile offshore, depth 28 feet. Limes sand bottom surrounds areas of what appear to be bare coral-algal limestone in horizontal layers. Scattered over the surface of the rock patches and also on the limesand are irregular blocks of dead coral. Patches of bright orange sponge were observed, but neither living plants nor corals were noted. April 6, 1949.

A-7—1.2 miles offshore (immediately south of uncovering reef SE of Mañagaha islet); depth 24 feet. Even to very slightly undulating bottom of fine- to coarse-grained limesand. April 6, 1949.

C-1—About 1,200 feet offshore; depth 10 feet. Limesand plain, dominantly coarse-grained and well sorted, with minor reef prominences up to about 20 feet in diameter. April 9, 1949.

C-7a—About 1.4 miles offshore; depth 8–9 feet around coral-algal bosses that rise to or near surface along line of transverse. Between coral and coral-algal masses the bottom is thinly coated with limesand, through which one can scrape to a hard undersurface of

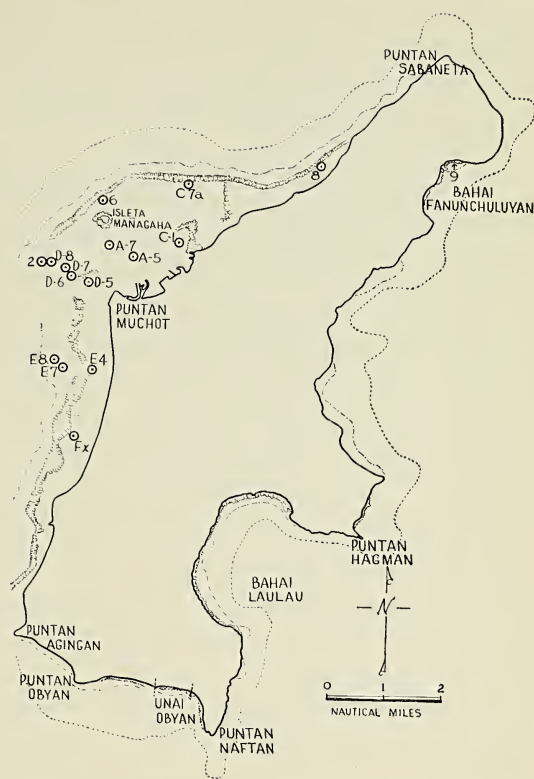


FIG. 1. Saipan, Mariana Archipelago,  $13^{\circ} 20' N$ ,  $140^{\circ} 40' E$ , showing collecting stations. The geographical designations are given in the local, non-anglicized, names (courtesy of Dr. P. E. Cloud, Jr.). Outer dotted line represents 100 fathoms, inner dashed line 10 fathoms. (Adapted from U. S. Hydrographic Office Chart 6060.)

crustose coralline algae with bare hands. April 10, 1949.

D-5—About 0.6 mile off Muchot point between reef clusters at south side of Saipan harbor; depth 5–15 feet. Generally similar to D-6 (see below), but with rocky bottom and a lesser total area of limesand nearby. Bottom at immediate point of collecting is one of mostly dead coral-algal rock with a fairly rich veneer of living crustose coralline algae. It rises to within five feet of the water surface at some places, but has deep cracks, channels, pothole-like depressions, and irregular depressions, some floored with angular gravel of broken coral and algal material. Into and cutting across this irregular rock surface are



limesand-floored channels up to perhaps 10 feet deep (15 feet below water surface) and for the most part sharply undercut into the base of the bordering overhanging coral-algal rock. May 6, 1949.

D-6—About 0.8 mile off Muchot point, near entrance to Saipan Harbor; depth 4–17 feet. Point of anchorage at a depth of 4 feet over the edge of a very irregular reef surface in which the primary builders of the present time are crustose coralline algae. Green algae are fairly abundantly scattered over the irregular reef surface, and into it extend tongues of clean limesand with ripple marks aligned approximately parallel to the reef front. These limesand tongues merge seaward with larger areas of limesand at depths of 15–17 feet. In pothole-like depressions on the reef surface are minor accumulations of angular gravel of broken coral and coralline algae. May 6, 1949.

D-7—About 1 mile off Muchot point, near entrance to Saipan Harbor; depth 22 feet. Collecting point immediately south of a mooring buoy over a narrow tongue of limesand between two rocky mounds—the one to the east rising about 12 feet above the bottom and being perhaps 100 yards long. Although drab and dead-looking, the surfaces of these and similar nearby mounds have a large proportion of living, purplish pink, crustose coralline algae. This calcareous algal growth, however, appears to be mostly a surface veneer over dead coral centers, a scattered growth of living coral still persisting in spots that have not been completely covered over by algae. May 6 and 13, 1949.

D-8—About 1.3 miles off Muchot point, immediately east of outer channel buoy, entrance to Saipan harbor; depth 36–42 feet. Bottom dominantly of dead coral-algal rock with irregular patches and thin local veneers of limesand and coral-algal rubble. Living coral and crustose coralline algae are found only as occasional bits on the generally dead and rocky surface, perhaps because of the general murkiness of the water here at the

harbor exit. The individual rocky mounds are low, rising to an approximately consistent level only a few feet above the intervening limesand. May 13, June 26, 1949.

E-4—About 0.4 mile offshore; depth 5–9 feet. Bottom of calcareous gravel and coarse limesand, interspersed with patches of ramose coralline algae. May 3, 1949.

E-7—About 0.9 mile offshore just beyond seaward edge of south limb of barrier reef west of Saipan; depth 25–34 feet. Bottom is a rough and irregular rocky surface of dead coral and coral-algal material on which are occasional patches of veneering limesand. A few small patches of veneering coral were seen, and a little living coralline algae; but most of the floor is dead rock with a scattering of encrusting green algae. May 3, 1949.

E-8—About 1.1 miles offshore, just north of Schildkrote Rock, seaward from the barrier reef west of Saipan; depth 32–38 feet. Bottom is very rocky, rising abruptly to Schildkrote Rock, which has points within two feet of mean low tide. May 4, 1949.

FX—About 0.7 mile offshore, depth less than 6 feet at low tide. Calcareous gravel and limesand bottom at inboard edge of reef. April 18, 1949.

LOC. 2—North side of passage into Saipan harbor. Depths 40–45 feet over bottom of interspersed limesand and patch reefs. Specimens taken from a half-ton coral rock brought up on a ship's anchor and broken up with sledge hammers and picks. April 28, 1949.

LOC. 6—Just north of Mañagaha islet in lagoon west of Saipan. Collections from lagoon fringe of barrier reef. June 1949.

LOC. 8—In shoal water over broad fringing reef at northwest end of barrier-fringing reef complex west of Saipan. Depths less than 6 feet at low tide. Knolls of dead coral-algal rock and living corals common on calcareous gravel and limesand bottom. Various times between December 1948 and June 1949.

LOC. 9—Fanunchuluyan Bay at northeast end of Saipan. Sand and gravel platform covered by as much as 5 or 6 feet of water at low

tide and locally with numerous irregular bosses of coral-algal rock and patchy coral growth behind seaward edge of a fringing reef, 300 to 700 feet wide. December 25, 1948.

Further information on these stations and the marine ecology of Saipan may be found in Cloud's chapter, "Marine Geology and Shoal Water Ecology" in the forthcoming *Geology of Saipan*.

In addition to these two collections, there is one specimen reported in this study that was collected on Guam (about 100 miles south of Saipan) by a Mr. Seale in 1900 which is in the Bernice P. Bishop Museum of Honolulu.

Cloud's study on Saipan was made under the sponsorship of the United States Geological Survey and the Corps of Engineers, United States Army. The present study was begun with support from a grant administered by the United States National Museum and the Pacific Science Board under a contract between the Office of Naval Research, Biology Branch, and the National Academy of Sciences (NR160-175); some help in the final typing was obtained with funds from a National Science Foundation grant (NSF-G-1754).

The specimens collected by Cloud, together with the type specimens from my collection, will be deposited in the United States National Museum; the disposition of my personal collection has not yet been decided and it may be deposited either in the National Museum or in the Bernice P. Bishop Museum.

#### AUTOMATE de Man

##### *Automate johnsoni* Chace

*Automate johnsoni* Chace, U. S. Natl. Mus., Proc. 105 (3349): 13, fig. 7, 1955.

LOCALITIES: Banner, 2 specimens in 2 collections; Cloud 1 specimen each at D-8, E-7, E-8.

DISCUSSION: Of the five specimens in the collection, only one, an ovigerous female, had the chelae intact.

It is difficult to decide how these few fragmentary specimens should be named. *A. johnsoni* is at least very closely related to *A. gardineri* Coutière (1905: 854), and, in the opinion of Chace, perhaps identical with it. In the series of slight differences between the two forms, the specimens from Saipan are somewhat intermediate, and appear to differ from both forms in yet other ways.

The rostrum in *A. gardineri* is rounded and separated laterally from the margins of the carapace by slight grooves, whereas in *A. johnsoni* and in the present specimens it is anteriorly rounded and without lateral grooves. The eyes in *A. gardineri* are variable in shape, but are irregular on the lateral and anterior margins according to the figures, whereas in *A. johnsoni* and the Saipan specimens the peduncles and corneas present a smooth curve from the base to the anterior medial margin. Chace points out that the second antennular article is 2.5 instead of 4.0 times as long as broad in his specimen; however, according to Coutière's figures the proportions in his type and cotype vary from 3 to 4 times as long as broad, and he states in his text that the proportions vary with the size of the specimen; in the Saipan specimens the proportion is about 3 to 1. In both *A. gardineri* and these specimens the stylocerite does not reach to the end of the first article, and the scaphocerite does not reach past the middle of the second article of the antennules, whereas in *A. johnsoni* the stylocerite exceeds the first article in length and the scaphocerite reaches within 0.2 of the end of the second article. Further, the superior surface of the ischium of the large chela bears a strong spine in the Saipan specimens, a weak spine in *A. johnsoni*, and lacks a spine (according to the figures) in *A. gardineri*; neither Coutière nor Chace show or discuss any rounded teeth on the dactylus of the large chela, yet they are quite easily seen on the chela of these Saipan specimens. Finally, in the second legs the first two articles are shown to have a ratio of 10:18 by Coutière, 10:12 by Chace, and are about 10:13



in the Saipan specimens (the right and left carpi have slightly different proportions in the distal articles of the intact female).

I suspect that the differences between *A. gardineri*, *A. johnsoni*, and the Saipan specimens are either individual variations or geographic differences of only subspecific worth, but until more complete specimens are examined from other areas, it would be best to leave the two species standing. These specimens from Saipan have been placed in *A. johnsoni* because of the similarity of the anterior carapace and rostrum.

ATHANAS Leach

**Athanas djiboutensis** Coutière

*Athanas djiboutensis* Coutière, Paris Mus. d'Hist. Nat., Bul. 3(6): 234, 1897a; Soc. Philomath. Paris, Bul. IX, 5(2): 75, 1903, and Fauna and Geogr. Mald. and Laccad. 2(4): 856, 1905. [These two identical papers are partial redescriptions.]

*Athanas sulcatipes* Borradaile, Zool. Soc. London, Proc., [1898]: 1011, pl. 65, fig. 9, 1898.

LOCALITIES: Banner, 22 specimens in 6 collections. Cloud, 3 at locality A-5, 1 at A-7, 3 at C-7a (13 May 1949), 2 at D-5, 2 at Loc. 8, 1 at Loc. 6.

DISCUSSION: These specimens agree well with the original and the redescription of Coutière, except for several points of variation both of which have been remarked upon before by Tattersall (1921: 367-368). The first is the length of the rostrum in respect to the antennular peduncle, described by Coutière (1905) as reaching "presque l'extrémité du pédoncule antennulaire"; in this large series of specimens only few approach this length, while most reach to near the end of the second antennular article and a few reach only the middle of the same article. A second point of variation is found in the form and armature of the large chela of the males. On this appendage the ischium bears from one (as shown by Coutière) to four strong mov-

able spines; the outer inferior margin of the merus may be entire, bear a slight rounded indentation, or be divided into two shallow and broad lobes, the distal approximately half the length of the proximal; the palm of the chela proper varies, being both slightly thicker and less tapering than is shown by Coutière, and, in proportion to the fingers, the palm is relatively longer; finally, the dactylus may be strongly curved and cross the immovable fingers as shown by Coutière, or be less curved and meet the opposite exactly. The conical protuberance of the carpus of the small chela of the female may be lacking and the surface of the carpus away from the chela may be rounded. No great significance is attached to these variations, especially as they have been previously noted by Tattersall, and as the variations appear independently of each other in the individual specimens.

The eyes appear to have some degree of motion, they may be either extended from under the carapace or withdrawn slightly. This small motion would not be noteworthy except that in this species and in other members of this genus the lengths of the circumorbital spines are often compared relative to these corneas as part of the specific description.

*Athanas dubius* sp. nov.

Fig. 2

TYPES: Holotype a 7.3 mm. ovigerous female, collected from Saipan by A. H. Banner; allotype a male 7.8 mm. long and 7 paratypes collected by A. H. Banner in three collections; 1 paratype collected by P. E. Cloud, Jr., from locality E-8. Types to be deposited in the U. S. National Museum.

DESCRIPTION: Rostrum acute, triangular, sides not curved, tip reaching to end of second antennular article (Fig. 2a has somewhat foreshortened rostrum); rostrum and carapace rounded, without carina. Supracorneal spines not reaching to middle of cornea; carapace between base of supracorneal spines and ro-

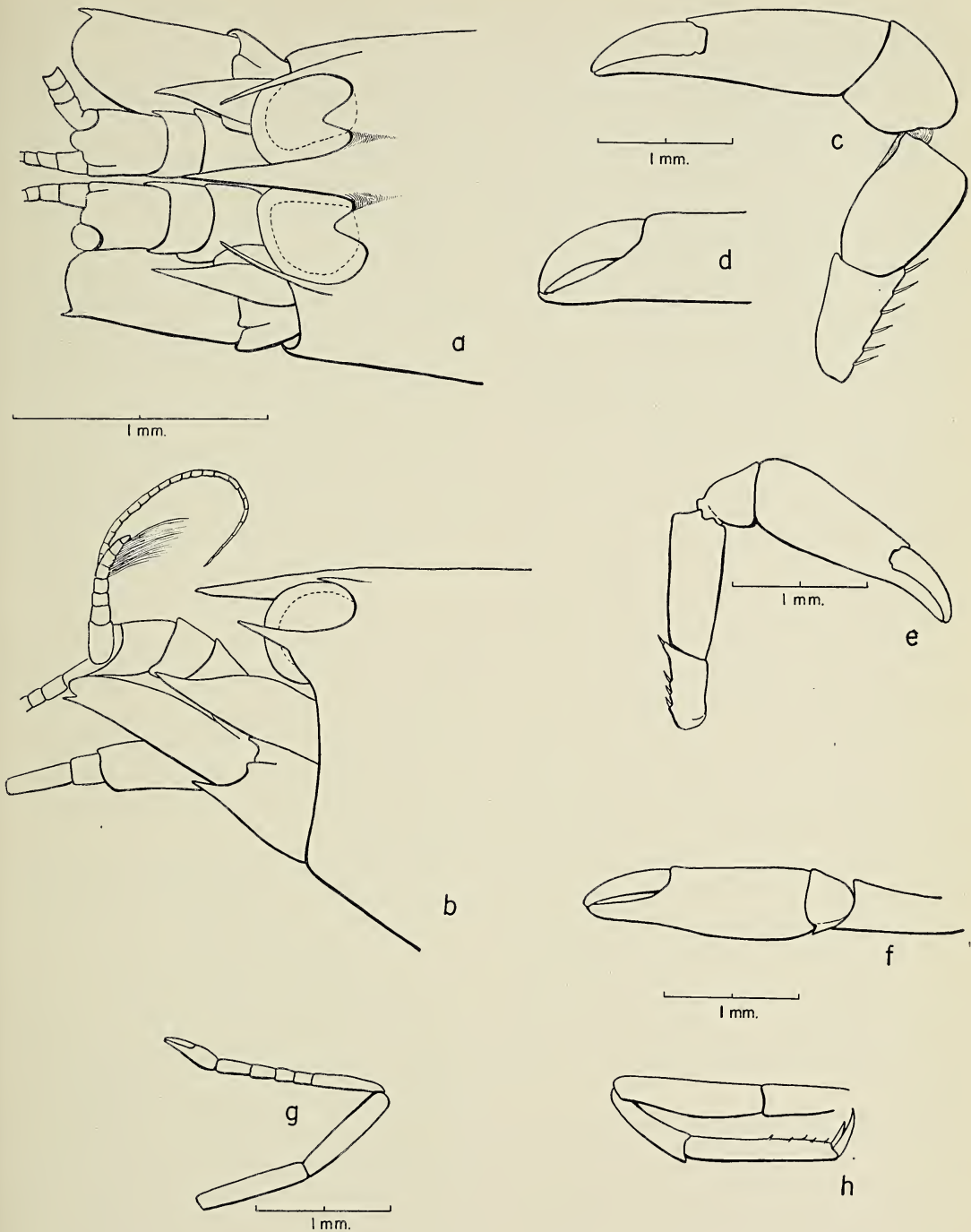


FIG. 2. *Athanas dubius* sp. nov. a, b, Anterior region, dorsal and lateral aspects; c, cheliped, male; d, large chela, finger, male; e, cheliped, female; f, chela, propodus and merus, female; g, second leg; h, third leg.



trum slightly depressed. Extracorneal spines strong, acute, reaching beyond corneas almost to end of first antennular article. Infracorneal spine absent, represented by a slight convexity on inferior margin of extracorneal spine. Pterygostomial angle rounded.

Portion of first antennular article in front of corneas about equal in length to second antennular article, latter about half as long as third article. Stylocerite acute, reaching end of second article. Lateral spine of basicerite reaching end of first antennular article. Scaphocerite with lateral spine very slightly longer than rounded portion, reaching slightly beyond end of antennular peduncle. Carpo-cerite shorter than scaphocerite.

Chelipeds showing slight sexual dimorphism and, in some cases, asymmetry. In type (female), large chela about 7 per cent longer than small chela, both of similar form. Ischium bearing four strong spines; merus unarmed, about 2.5 times as long as broad; carpus rounded, somewhat elongate, with distal end enclosing base of palm; chela almost cylindrical, slightly inflated proximally, three times as long as broad, with fingers occupying about distal third; fingers without teeth, dactylus slightly curved. Large chela in allotype slightly over 10 per cent longer than small chela, but of similar form. Ischium 0.8 as long as merus and bearing six strong spines; merus heavy, 0.6 as broad as long, half as long as chela, unarmed; carpus heavy, cylindrical and fitting over base of chela; chela cylindrical, tapering, 0.3 as broad as long, with fingers occupying slightly less than distal third; fingers unarmed, dactylus curved distally.

Carpal articles with ratio: 10: 2.6: 3.2: 3.7: 5.9.

Ischium of third legs unarmed, 0.5 as long as merus; merus unarmed, 0.2 as broad as long; carpus 0.6 as long as merus, 3 times as long as broad; propodus equal in length to merus, bearing 5 small spinules in distal half, terminal movable spine 0.6 length of dactylus; dactylus 0.3 length of propodus,

simple, slightly curved and gradually tapering to acute tip.

Telson half as wide posteriorly as anteriorly, 3.6 times as long as posterior margin is broad; sides straight with uniform taper; distal margin moderately convex; both dorsal spinules located posterior to middle.

Eggs of type specimen  $0.32 \times 0.50$  mm. in diameter.

DISCUSSION: In the group of paratypic specimens some variations are found, especially in the armature of the chelipeds. The number of spines on the ischium in the females varies from three to six, usually five or six; in the males the spines, always stronger than those of the female, vary in number from five to six. In some of the males the distal external angle of the merus is produced into a strong but rounded lobe; in one female the superior angle of the distal end of the merus carries a rather weak movable spine. Further, the degree of asymmetry varies from chelae that are equal to to slightly more asymmetrical than those of the types. Finally, on one female the carpus of the second legs on one side is divided into four articles while the other has the normal five. No marked variation was noticed in the other parts of the body or appendages.

The validity of this species is somewhat questionable for it is closely associated with *A. areteformis* Coutière (1903: 79; 1905: 860) and *A. erythraeus* Ramadam (1936: 13). Unfortunately the description of neither of these two species is complete. All three belong to the *nitescens* group of the genus in which the chelae are carried directed forward. All three also have simple dactyli on the posterior legs, the supracorneal spine well developed, the extracorneal spine greatly produced, and the infracorneal spine wanting. *A. dubius* differs from *A. areteformis* in that the dactylus of the large chela of the male is relatively longer, being over 0.6 the length of the palm in the former and 0.3 the length of the palm in the latter; in the latter, moreover, this dactylus is strongly curved. In comparing the chelae

of the female of *A. dubius* to *A. naifaroensis* (which Coutière states "... ne diffère aucune-ment. . .") it is found that the palm is less expanded in *A. naifaroensis*, being without taper and having its breadth equal to only half the length of the fingers, instead of being equal to the length of the fingers as in *A. dubius*, also the ischium is unarmed in *A. naifaroensis* whereas in *A. dubius* it bears 3-6 spines.

There are also slight differences between *A. dubius* and *A. erythraeus*. Ramadam states that in the latter the sides of the rostrum are parallel for some distance from the proximal end, whereas in the former there is a uniform taper from the base to the tip; in his specimen, a female, the fingers of the chela have slightly rounded teeth, two on the side of the dactyl, one on the immovable finger, and in mine the fingers bear straight knife-like cutting edges.

However, these differences, and the differences between *A. erythraeus* and *A. areteformis*, are very slight, and the similarities, especially in the form of the anterior carapace and appendages, are great. It is reasonable to expect that when specimens are collected at localities between Ghardaqa in the Red Sea and the Maldives and Laccadive archipelagoes in the Indian Ocean and between these archipelagoes and the Marianas, intermediate forms may be found.

#### ARETE Stimpson

##### *Arete iphianassa* de Man

*Arete iphianassa* de Man, Ned. Dierk. Ver., Tidschr. II, 11(4): 312, 1910; Siboga Exped., 39a<sup>1</sup>(2): 164, pls. 3-4, fig. 11, 1911.

LOCALITIES: Cloud, 4 specimens at locality C-7a (2 each on 10 April and 13 May, 1949), 1 at D-8, 1 at Loc. 6.

DISCUSSION: These six specimens agree almost exactly with de Man's description and figures except that the tooth on the dactylus of the large chela of the male is less pronounced than shown in de Man's figure 11a.

#### ALPHEOPSIS Coutière

##### *Alpheopsis equalis* Coutière

*Alpheopsis equalis* Coutière, Paris Mus. d'Hist. Nat., Bul. 2(8): 380, 1896.

*Alpheopsis aequalis* de Man, Siboga Exped., 39a<sup>1</sup>(2): 177, 1911.

LOCALITIES: Banner, 17 specimens in 5 collections: Cloud, 1 specimen at Loc. 6.

DISCUSSION: These specimens show much of the variation in the rostrum, pterygostomial angle, coverage of the eyes, and in the large chelae like that already reported from Hawaii (Banner, 1953: 16). In addition they present several variations worthy of note. First, the base of the rostrum in most specimens is set off from the anterior portion of the carapace by definite angles, but in one specimen the margins of the carapace are continuous in a gradual concave curve to the tip of the rostrum, and in several specimens the condition is intermediate. Second, the ratio of the middle articles of the carpus is also variable, with the second article running from a third shorter to a third longer than the third article; the ratio of the lengths of the third and fourth articles also varies but less conspicuously. Finally, in a specimen normal in all other respects the carpus of the second leg is divided into six, rather than five articles. This development is symmetric, and the extra article appears to be equal in length to the normal third article and is adjacent (either proximal or distal) to it.

##### *Alpheopsis diabilus*, sp. nov.

Fig. 3

TYPE: A 9.2 mm. ovigerous female, collected by A. H. Banner.

DESCRIPTION: Anterior portion of carapace produced as short, triangular rostrum reaching two-thirds of length of visible portion of first antennular article, and as triangular extracorneal spines about half the length of rostrum; without ridges or depressions. Pigmented portion of cornea concealed in dorsal



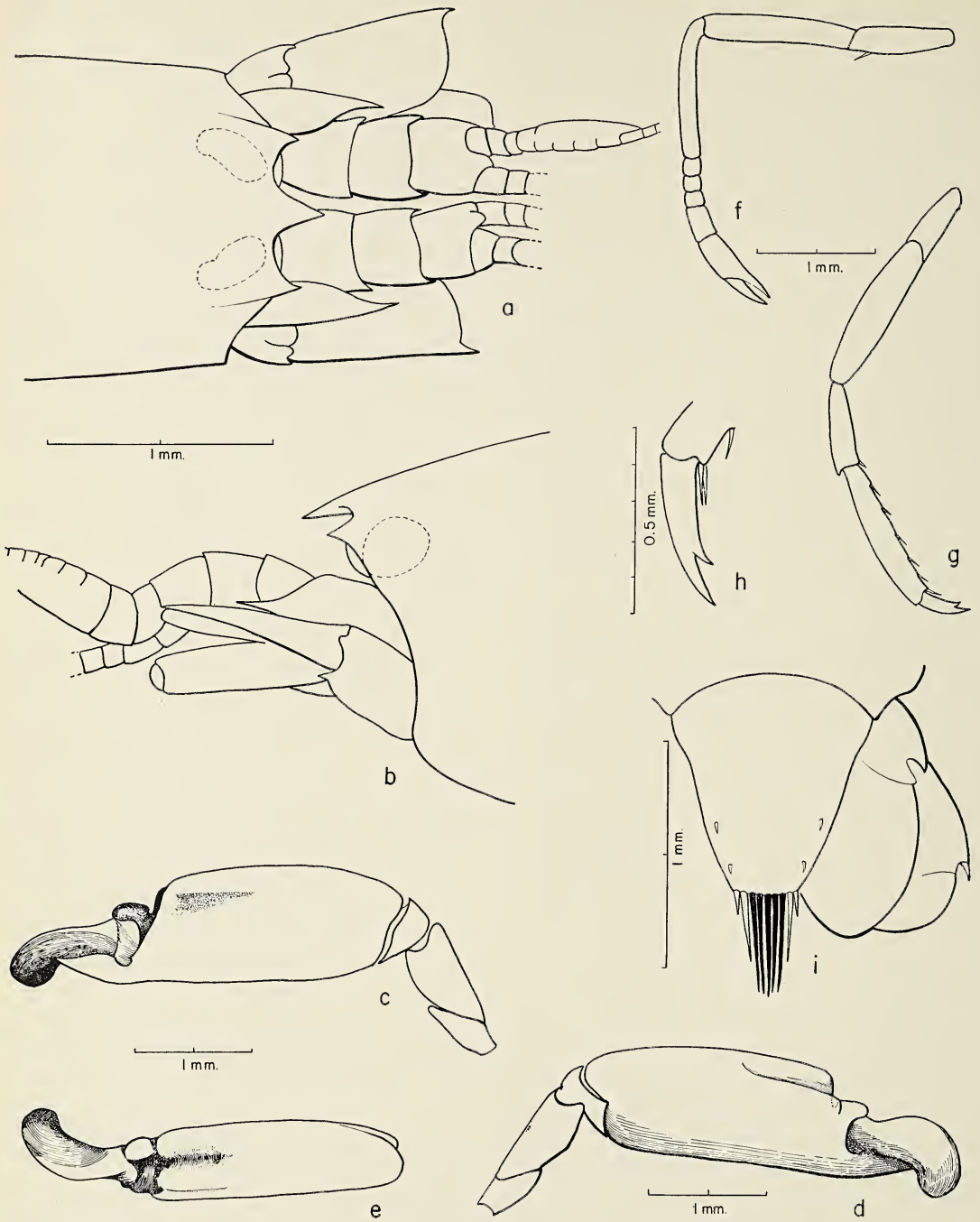


FIG. 3. *Alpheopsis diabolus* sp. nov. *a, b*, Anterior region, dorsal and lateral aspects; *c-e*, large cheliped, lateral, medial and superior aspects; *f*, second leg; *g*, third leg; *h*, third leg, dactylus; *i*, telson and uropod.

and lateral view, but outer margin of eyes visible in both aspects. Pterygostomial angle rounded.

Visible portion of first antennular article 1.3 times length of second article; second article approximately as long as third article and slightly broader than long; stylocerite acute with tip reaching to middle of second article; outer flagellum with basal portion before bifurcation very broad; bifurcation feeble. Basicerite of antennal peduncle with distal lateral tooth; scaphocerite with strong distal lateral tooth, slightly exceeding the length of rounded portion, subequal in length to antennular peduncle; carpocerite slightly longer than scaphocerite.

Merus of large cheliped as broad as inferior margin is long, subequal to maximum length of ischium; ischium and merus unarmed. Carpus short, rounded, with triangular projection on middle of inner margin. Chela compressed, superior and inferior margins rounded. Palm twice as long as ischium and merus combined, slightly over twice as long as broad; outer face with shallow rounded groove extending from dactylar articulation one-third length of palm; superior face marked by deep groove separating two sharp ridges, equal in length to lateral groove. Dactylus articulated to close about  $60^\circ$  to plane of chela, across pointed fixed finger; superior articular surface of propodus carried in rounded prominence beyond crests and grooves of palm to accommodate rotation. Dactylus broad, curved and flattened, without teeth, 0.4 length of palm. Only small tufts of setae located near fingers on chela.

Small cheliped lacking.

Carpus of second legs with ratio: 10: 1.5: 1.5: 1.5: 2.; short articles about as long as broad.

Second legs with ischium unarmed; merus 2.3 times length of ischium and 4.5 times as long as broad, unarmed; carpus 0.5 length of merus, with small movable spine on inferior distal angle; propodus as long as merus, armed with five inferior and two distal slender

spines; dactylus 0.3 length of propodus, with strong accessory tooth on inferior margin.

Pleura of sixth abdominal segment articulated.

Telson short and broad, 3.2 times as long as tip is broad, 3.0 times as broad anteriorly as at tip; tip almost straight, bearing two pair of spines, five heavy setae; longer spines three times as long as shorter, equal in length to breadth of tip of telson; anterior pair of dorsal spinules located about 0.7, posterior pair about 0.85 distance from base of telson, both pairs located near lateral margins. Outer uropod with strong spine at articulation; both uropods longer than telson.

Branchial formula with five pleurobranchs, one arthrobranch and eight epipodites.

Eggs few,  $0.62 \times 0.36$  mm. in diameter.

DISCUSSION: This species plainly belongs to the genus *Alpheopsis* as is shown by the articulated pleopods of the sixth abdominal segment, by the general form of the anterior portion of the carapace and by the branchial formula. The form of the chela is somewhat similar to that of *A. trispinosus* (Stimpson) and *A. chilensis* Coutière (see Coutière, 1899, figs. 228–232).

Within the genus, however, it differs from all other forms except *A. fissipes* Coutière and (?) *A. biunguiculatus* Banner in the presence of biunguiculate dactyli on the third to fifth legs. From *A. fissipes* it differs principally in the presence of extracorneal teeth, the greatly elongate first carpal article of the second leg, and the difference in proportions and armature of the third legs. Similarly, it differs from (?) *A. biunguiculatus* in the extracorneal teeth, the carpus of the second legs, and the armature of the propodus of the third legs; it also differs in the branchial formula and the form of the telson. (In neither of these species are the chelae known.) As far as I have been able to determine, the form of the large chela, with the double grooves and the rotation of the flattened and unarmed dactylus is unique within the genus; however, in many of the species the chelae have not been described.



This specific name refers to the split unguis.

*Alpheopsis tetrarthri* sp. nov.

Fig. 4

TYPE: A 6.0 mm. female collected from a head of dead coral at Loc. 2 by Preston E. Cloud, Jr., 28 April 1949. Type to be deposited in the U. S. National Museum.

DESCRIPTION: Anterior carapace projecting as a broad curved collar, reaching almost to end of first article of antennular peduncle; anterior margin uniformly curved; dorsal surface smooth, without ridges or bosses. Rostrum small, triangular in dorsal view, tip reaching about to end of first third of second antennular article; in lateral view appears to be composed of a lamella hanging ventral to carapace proper, tip strongly depressed. Ptery-

gostomial angle projecting as acute spine; no other spines of anterior carapace developed.

Cornea of eyes large, entirely concealed from dorsal and lateral view by carapace.

Antennular peduncle short, heavy, with second article about as broad as long, approximately as long as third article; first article barely visible under projecting edge of carapace. Stylocerite acute, reaching to middle of second article, slightly beyond tip of rostrum. Flagella of usual size, about twice as long as peduncle. External flagellum with broad base bearing tuft of long bristles, but without trace of bifurcation.

Basicerite of antennal peduncle without tooth. Scaphocerite broad, well developed, with lateral spine small, reaching anterior tip of curved portion; tip of scaphocerite definitely exceeding antennular peduncle in

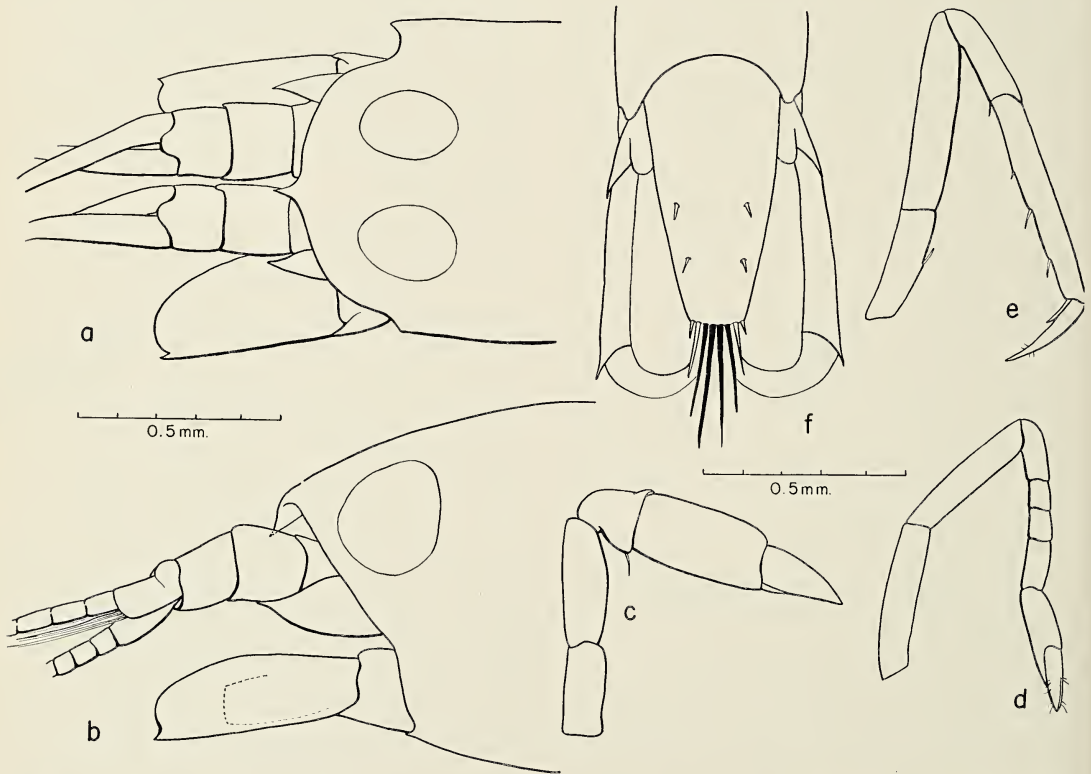


FIG. 4. *Alpheopsis tetrarthri* sp. nov. a, b, Anterior region, dorsal and lateral views (outline of distal portion of carapocerite dotted in b); c, cheliped; d, second leg; e, third leg; f, telson and uropods.

length. Carpocerite short, reaching only slightly beyond end of second antennular article.

Mouthparts not dissected.

One of first chelipeds lost. Chela of leg remaining small, as long as ischium and merus combined; palm about twice as long as broad, 1.5 times as long as tapering slender fingers. Carpus as broad as long, slightly cyanthiform distally. Merus rounded-triangular in section, about 2.5 times as long as broad. Ischium 0.7 as long as merus, of same width.

Second legs with carpus of only four articles with ratio: 10: 5: 7: 9. Chela relatively large, as long as merus.

Third, fourth, fifth legs similar. On fourth leg ischium 0.6 as long as merus, bearing movable spine; merus five times as long as broad, unarmed; carpus half as long as merus; propodus slightly longer than merus, bearing three slender spines on inferior margin, one distally; dactylus half as long as merus, slender, tapering to fine tip.

Pleura of sixth abdominal segment articulated.

Telson twice as long as broad anteriorly, with tip 0.4 as broad as base; two pairs of dorsal spines, anterior located at half length of telson, posterior midway between anterior pair and tip; tip shallowly arcuate, bearing four spines, longer pair as long as tip of telson is broad, four heavy setae. Uropods of usual form.

Branchiae difficult to discern, but apparently with five pleurobranchs, arthrobranchs either rudimentary or entirely lacking; seven or possibly eight epipodites.

DISCUSSION: Unfortunately this species is represented by a single defective specimen, possibly also immature. It appears to belong to the genus *Alpheopsis*. The form of the carapace and rostrum are similar to that of *Alpheopsis equalis* except that the carapace extends much farther forward and the rostrum is relatively smaller; the antennular and antennal peduncles are of the same general form

as *A. equalis* but of slightly different proportions; the small chela is almost identical to the small chela of *A. equalis*, as are the third and fourth legs; the telson and uropods, and the articulated sixth pleopods of the abdomen are also similar. The principal differences between *tetrarthri* and the other species of the genus are the presence of four articles in the carpus of the second leg in this species whereas in the others there are either three articles (*A. idiocarpus* Coutière) or five and a difference in the branchial formula which in this species is apparently 5-0-7, instead of 5-1-6 or 5-1-8. (It should be noted that (?) *Alpheopsis biunguiculus* Banner (1953: 19) has a rudimentary arthrobranch and only seven epipodites.) The species is assigned to this genus in spite of these possible fundamental differences because it has been accepted already that the number of articles in the carpus is not fixed in this genus, and because I could not determine the branchial formula to my satisfaction without tearing this unique specimen apart. Without the large chela, even if all the other characteristics were in complete agreement, any generic identification would be tentative.

Within the genus *Alpheopsis* this species can be separated readily from all other species by the presence of only four articles in the carpus of the second leg and by the extreme prolongation of the anterior margin of the carapace. Other minor differences occur between *tetrarthri* and the other species such as the proportions of the stylocerite and antennular peduncle; the proportions of the scaphocerite and antennal peduncle; the simple or bifid dactylus of the third legs; and the proportions of the telson.

SYNALPHEUS Bate  
Neomeris group

*Synalpheus charon obscurus*, subsp. nov.

Fig. 5

*Alpheus charon* Heller, K. Akad. Wiss. Wien, Sitzungber. 44: 272, 1861.



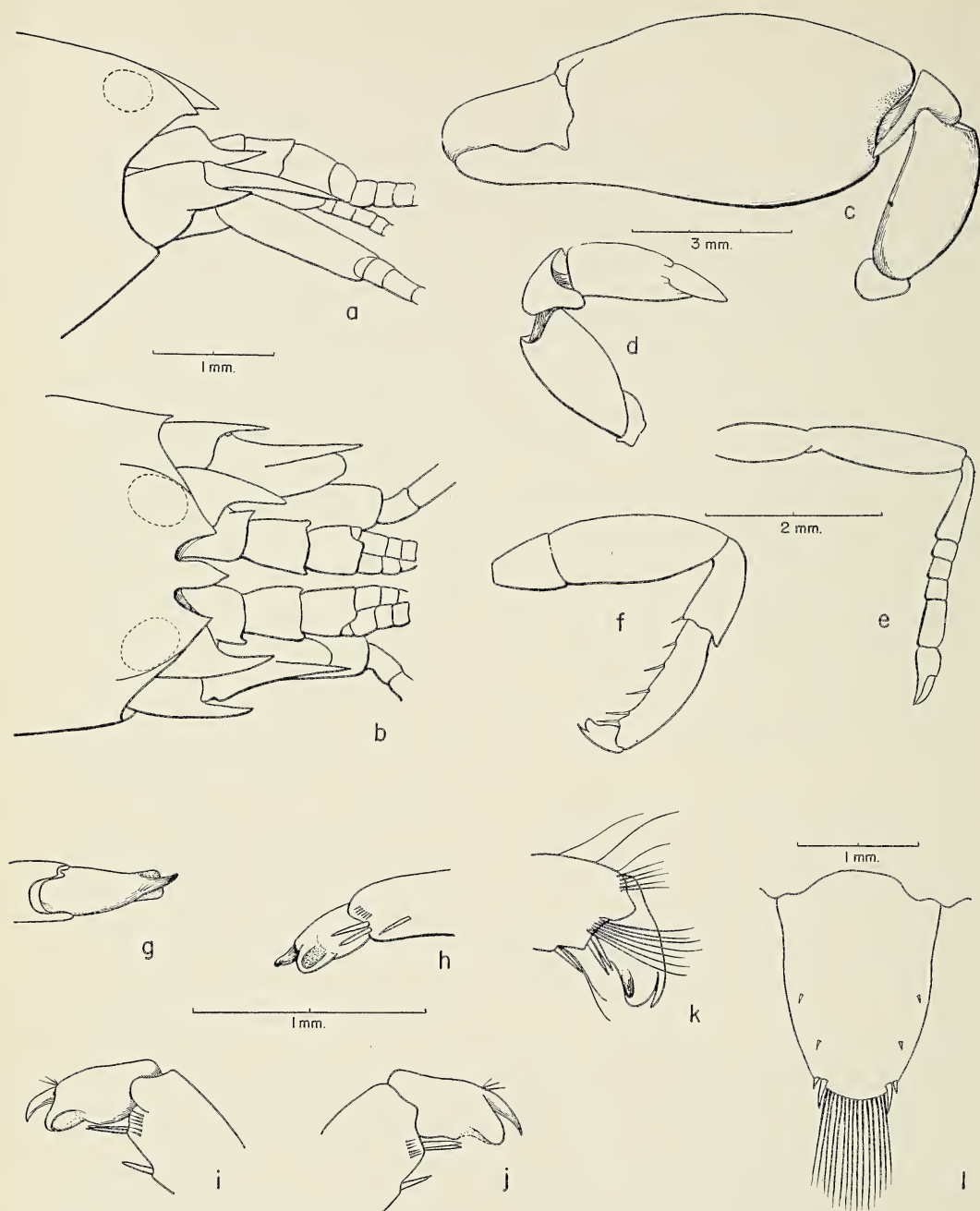


FIG. 5. *Synalpheus charon obscurus* subsp. nov. *a, b*, Anterior region, dorsal and lateral aspects; *c*, large cheliped; *d*, small cheliped; *e*, second leg; *f*, third leg; *g, h, i, j*, dactylus, third leg, superior, inferior, medial or anterior, and lateral or posterior aspects; *k*, dactylus, fourth leg; *l*, telson.

**TYPES:** Holotype a 13.5 mm. ovigerous female, collected by A. H. Banner from the reef flat on the S. E. side of Unai Obyan, Saipan, 25 December 1944; allotype, a 9.3 mm. male from the same location; paratypes, 14 other specimens from three collections, A. H. Banner, collector.

**DESCRIPTION:** Body heavy, compact. Rostrum with basal portion parallel sided, slightly over distal third tapering, tip acute, not reaching end of first antennular article. Orbital hoods acuminate, tips of orbital teeth not reaching end of rostrum.

First and second articles of antennular peduncle subequal in length, third slightly shorter. Stylocerite heavy, tip reaching to middle of second antennular article. Lateral spine of basicerite heavy, slightly shorter than stylocerite. Lateral tooth of scaphocerite as long as antennular peduncle, definitely longer than the squamous flattened portion.

Merus of large cheliped unarmed, slightly curved, twice as long as broad. Chela 2.5 times as long as broad, with heavy fingers occupying distal 0.28; superolateral margin of palm continued over dactylar articulation as slight rounded tooth. Merus of small cheliped likewise unarmed; carpus slightly greater in diameter than palm of chela. Chela small, 0.3 the length of the large chela, 0.3 times as broad as long, with fingers occupying distal 0.4.

Carpal articles of second legs with ratio: 10:2.3:2.7:2.7:6.2.

Ischium of third legs unarmed, about one third as long as merus; merus unarmed, 2.4 times as long as broad; carpus half as long as merus, armed with single movable spine on inferodistal angle; propodus 0.8 as long as merus, bearing four inferior and two distal spines; dactylus heavy, with superior unguis simple, tapering, inferior unguis massive, concave on inferior surface; dactylus may or may not be flanked with long setae arising from distal end of propodus.

Telson 2.8 times as long as posterior margin is broad, and 2.0 times as wide anteriorly as

posteriorly; margins without uniform taper, but concave in anterior third, convex in middle third and almost straight (but not parallel) in distal third. Dorsal spinules small.

Eggs numerous,  $0.41 \times 0.63$  in diameter.

Male similar to female in form and proportions.

**DISCUSSION:** This subspecies can be separated from the typical subspecies, *S. charon charon*, by the following characteristics: 1, The rostrum is parallel-sided in at least the basal half rather than uniformly tapered. 2, The meri of the third legs, are 2.4 instead of 3.0 times as long as broad. 3, The superior unguis of the dactyli of the third legs is not as broad basally and has a uniform taper to the tip rather than with a broad basal plate which is abruptly narrowed to a curved tip. Otherwise the two varieties are almost identical aside from minor and insignificant differences in the proportions of the second legs, telson, etc.

Because of the unique concavity of the dactyls of the posterior legs, found only in *S. charon* in this genus, it was considered that this form is merely a subspecific modification. On Saipan no true *S. charon charon* were collected; however, in the Gilbert Islands both subspecies were found (to be reported upon in a later publication).

### *Synalpheus paraneomeris* Coutière

Fig. 6

*Synalpheus paraneomeris* Coutière, Fauna and Geog. Mald. and Laccad. 2(4): 872, pl. 71, fig. 7, 1905.

**LOCALITIES:** Banner, 64 specimens in 6 collections; Cloud, 19 specimens at Loc. D-6, 8 at Loc. 6.

**DISCUSSION:** The variation in this species has been discussed by Coutière (*loc. cit.*) and Banner (1953: 40 *et seq.*). The great variation noticed in the Hawaiian specimens is duplicated and even exceeded in the specimens from Saipan. Like the Hawaiian specimens, they vary in the length of the rostrum relative



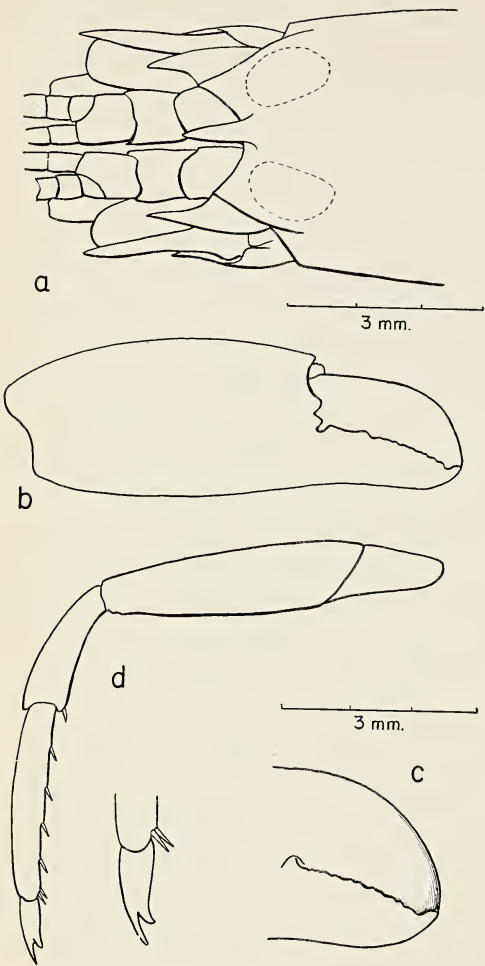


FIG. 6. *Synalpheus paraneomeris* Coutière. Aberrant specimen. *a*, Anterior region, dorsal aspect, showing asymmetry in orbital hoods; *b*, large chela, lateral aspect; *c*, large chela, fingers, showing details of teeth; *d*, third leg; *e*, third leg, dactylus enlarged.

to the orbital teeth and antennular peduncle, in the antennular peduncle, in the basicerite and scaphocerite of the antennal peduncle, in the large cheliped, in the relative lengths of the carpal articles of the second legs, in the dactyli of the third legs, in the general proportions of the telson. In addition, variations occur in the relative length of the carpocerite, which varies from only slightly longer to considerably longer than the scaphocerite, and in the rostrum and in the large cheliped.

In the 19 specimens from Cloud's collec-

tion D-6 the length of the rostrum relative to the lengths of the orbital hoods, and its relative breadth were measured. (In one specimen the rostrum was entirely lacking, a condition interpreted as the result of an accident of heredity or environment.) The ratio of rostral length to orbital hood length ranged from 1:1 to 1.6:1, with the following distribution:

ROSTRAL LENGTH ÷ LENGTH ORBITAL HOOD	SPECIMENS
1.0.....	3
1.1.....	4
1.2.....	4
1.3.....	2
1.4.....	1
1.5.....	0
1.6.....	4

ROSTRAL LENGTH ÷ ROSTRAL WIDTH AT BASE	SPECIMENS
1.5.....	3
2.0-2.9.....	6
3.0-3.9.....	7
4.0-4.5.....	2

In a collection of 25 specimens made by the author, a series of specimens in which all chelae were intact, the relative lengths of the fingers were measured, and these measurements correlated with the sex of the specimens and are tabulated below:

CHELA LENGTH ÷ FINGER LENGTH	SPECIMENS	
	Male	Female
2.9.....	2	
3.0.....	2	
3.1.....		
3.2.....	1	1 (?)
3.3.....		
3.4.....		
3.5.....	1	2
3.6.....		3
3.7.....		4
3.8.....		3
3.9.....		1
4.0.....	1 (?)	2
4.1.....		
4.2.....		2

The interpretation of this second series of variations is simple: the length of the fingers relative to the chela is a sexually dimorphic

characteristic. (It should be remarked that males in other samples from Saipan had a ratio as low as 2.8:1.) The interpretation of the variations in the rostrum is more difficult, especially in view of the four specimens which seem so different in having the rostrum 1.6 times as long as the orbital hoods. However, these four specimens did not bear correlating difference in their other characteristics; for example, their rostral width ratios were 1.6, 1.6, 3.3, and 4.3, or, in words, two had very broad rostrums, one average, and one very narrow. So it would appear that this, too, was merely a variation.

In one collection there are two males with the chela:finger ratio of 3.0:1 in which the cutting edge of the fixed finger had shallow denticulations. One of these specimens is shown in Figure 6. The specimens are within the range of variation for the species, although the unguis of the dactylus of the third legs is a bit narrower and more parallel-sided than is usual for the species.

This species is the most perplexing I have encountered. If such wide variation is found here, why do other species appear to be so constant? Then, should not this be interpreted as more than one species? If the variations were discontinuous, or even if the variations were continuous, but their continuity could be established only by samples from separate localities or habitats—if, for example, those with the short rostrums were only found in the Marianas, those with long rostrums in Hawaii, and those in the intermediate condition were found in Micronesia—then descriptions of separate subspecies or species would be justified. But such separation seems unjustified when the range of variation is found in one habitat and in specimens collected at one time. If such variation is found in *S. paraneomeris*, should not similar variation be looked for in other species which are separated by small, but discrete, differences? For example, *S. biunguiculatus* (Stimpson) (as redescribed by Banner, 1953: 33) basically is separated from this species by the relatively

smaller lower unguis of the dactylus of the third leg—could not this, too, be an inherent variation that may be ignored by a breeding population? I fear that the answer to this fundamental question can be arrived at only by the almost impossible task of raising the shrimp through several generations.

#### Coutierei Group

#### *Synalpheus coutierei exilipes* Coutière

Fig. 7

*Synalpheus biunguiculatus* var. *exilipes* Coutière, Fauna and Geog. Mald. and Laccad. 2(4): 874, pl. 71, fig. 10, 1905. [*nec. Alpheus biunguiculatus* Stimpson, Acad. Nat. Sci., Phila., Proc. 1860: 31] *Synalpheus coutierei* Banner, Pacific Sci. 7(1): 36, 1953.

LOCALITY: Cloud, an 8.5 mm. ovigerous female collected at Loc. 6.

DESCRIPTION: Rostrum narrow, tapering, suddenly acute at tip, tip reaching almost to end of first antennular article. Orbital teeth narrow, tapering, slightly shorter than rostrum; orbital hoods slightly inflated anteriorly.

Second antennular article 1.4 times as long as broad, or as long as first article, and one third longer than third article. Stylocerite as long as first antennular article and as lateral spine of basicerite. Basicerite with superior lateral angle projecting as small acute tooth. Scaphocerite as long as antennular peduncle. Carpocerite 6.5 times as long as broad in lateral view, tip reaching beyond end of antennular peduncle.

Large chela of usual shape for genus, 2.7 times as long as broad, with fingers occupying distal 0.2. Merus twice as long as broad, superior margin slightly arcuate and terminating in feeble tooth. Small chela with fingers tapering, occupying distal 0.4.

First carpal article of second leg equal to the sum of the lengths of the four following; second, third, and fourth articles subequal;



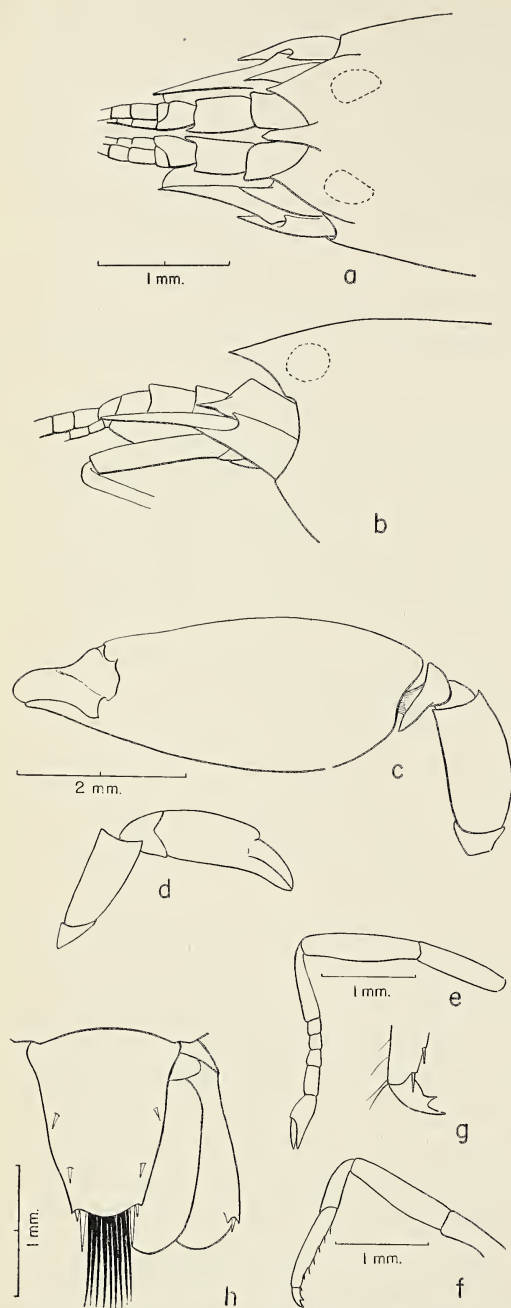


FIG. 7. *Synalpheus coutierei exilipes* Coutière. a, b, Anterior region, dorsal and lateral aspects; c, large cheliped; d, small cheliped; e, second leg; f, third leg, g, third leg, dactylus; h, telson and uropods.

fifth article slightly shorter than the lengths third and fourth combined.

Merus of third legs unarmed, tapering dis-

tally, 4.0 times as long as broad. Carpus 0.38 as long as merus, with superior margin terminated by tooth. Propodus 0.8 as long as merus, bearing six inferior and two terminal weak spines. Dactylus about 0.25 as long as of propodus, heavy, with superior unguis thin, curved and acute, inferior unguis at about 90° to inferior margin of dactyl, triangular, acute and broader at base than superior unguis.

Telson 2.7 times as long as posterior margin is broad, 2.2 times as broad anteriorly as posteriorly; lateral margins as shown in Figure 7b; posteriolateral angles slightly projecting and acute; posterior margin arcuate. Anterior pair of dorsal spinules slightly before the middle, posterior pair 0.8 of length posterior from base.

DISCUSSION: This specimen shows a series of differences from Coutière's subspecies (or variety). The rostrum and the orbital teeth are slightly shorter, the first antennular article is slightly longer, the lateral spines of the stylocerite and the basicerite are slightly shorter. Coutière did not describe the large and small chelae, but if the large chela bore a tooth as did his *S. biunguiculatus* (*op. cit.*, fig. 8a), there, too, lies a difference. However, the proportions of the third legs are almost exactly the same with the depicted dactyli varying on either side of the condition found here.

Certainly the two forms are not identical, but they are so similar that in light of the variation in *S. paraneomeris* Coutière, no great importance should be attached to the slight differences. However, it is possible that if there were a series of specimens available the differences would be found to be constant enough to consider this as a distinct subspecies.

#### *Synalpheus anceps* sp. nov.

Fig. 8

TYPES: Holotype, an ovigerous 9.5 mm. female, collected from Saipan by A. H. Banner. Allotype, a 7.3 mm. male; paratypes, 13 specimens of both sexes, all collected by

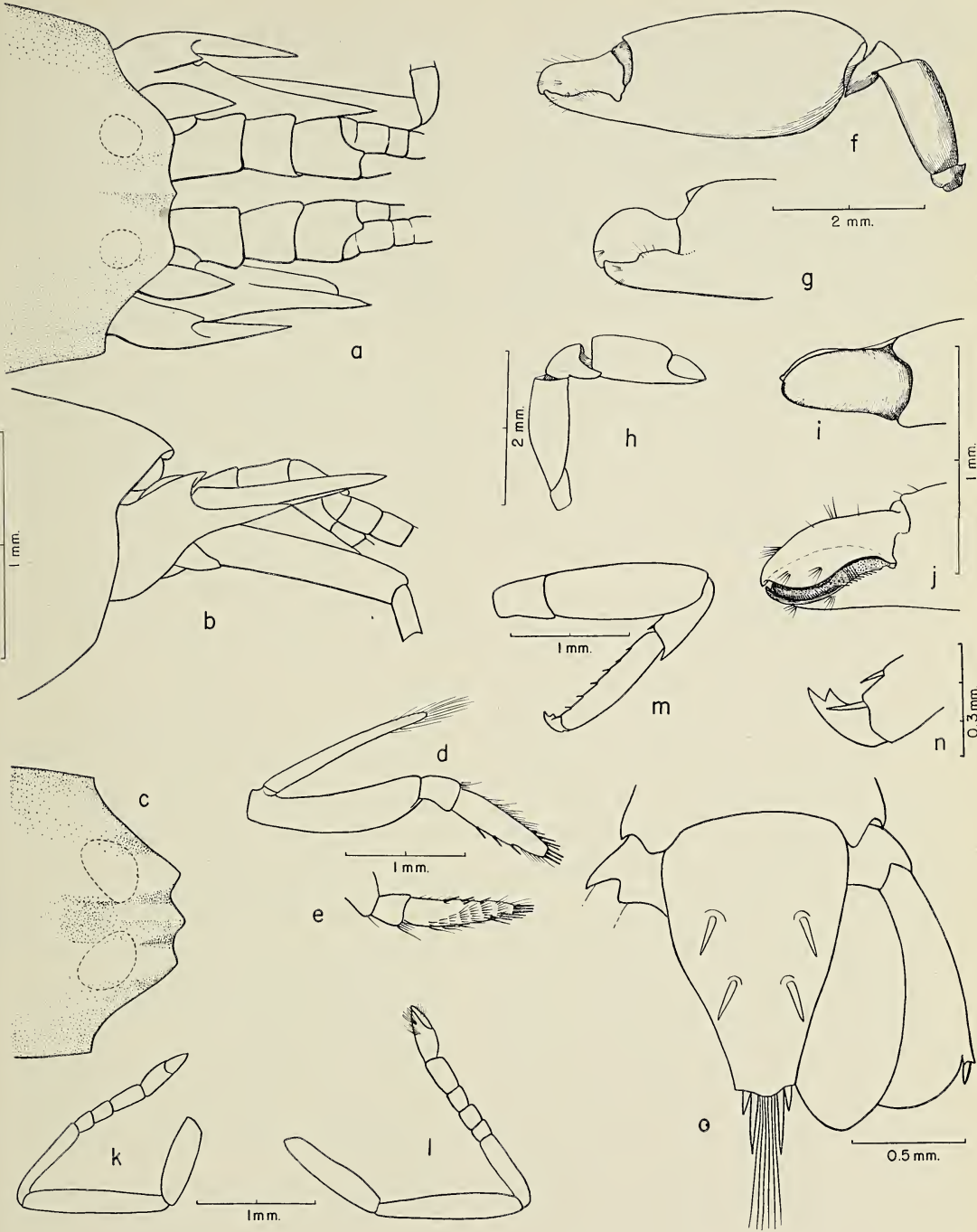


FIG. 8. *Synalpheus anceps* sp. nov. *a, b*, Anterior region, dorsal and lateral aspects; *c*, anterior region, another specimen; *d, e*, third maxilliped; *f, g*, large cheliped; *h*, small cheliped; *i*, spatulate dactylus of small cheliped, type; *j*, same, paratype female; *k*, second leg, right side; *l*, same, left side; *m*, third leg; *n*, third leg, dactylus; *o*, telson and uropod.



Banner at three different times. Types to be deposited in the U. S. National Museum.

DESCRIPTION: Anterior portion of carapace almost truncate anterior to eyes, rostrum produced into very slight angle; in lateral view anterior margin depressed; orbital hoods low but slightly higher than median area of carapace; rostral carina short, low and rounded. Pterygostomial angle of carapace slightly projecting but rounded; cardiac notch present. Cornea of eyes visible under carapace in lateral view.

Second antennular article 0.8 as long as broad, 0.7 as long as visible portion of first and 0.8 as long as third article. Stylocerite slightly shorter than basal article, acute but with lateral spine poorly developed. Outer flagellum with secondary ramus consisting of two articles; both flagella only slightly longer than base.

Basicerite with superior tooth heavy but short, subacute; lateral tooth heavy, long and acute, reaching to end of second antennular article. Scaphocerite with heavy lateral spine reaching beyond end of antennular peduncle, 1.2 times as long as the narrow squamous portion. Carpocerite longer, slender, reaching considerably beyond end of scaphocerite.

Third maxillipeds of normal form, with inner face of terminal article bearing numerous bristles and movable spinules.

Merus of large cheliped triangular, with definite margins between the faces, outer face 2.3 times as long as broad; superior distal and inferior internal angles unarmed. Carpus expanded and short. Chela 2.4 times as long as broad, 3.3 times as long as fingers, rounded in side view, laterally slightly compressed; short, heavy, rounded tooth above dactylar articulation. Dactylus heavy, compressed, with distal margin strongly arcuate; dactylus with usual "plunger" and without adhesive plaques. Very light scattered setae on both fingers.

Small cheliped with merus as long as that of large chela, but more slender. Carpus hemispherical but with inferior projecting flange

that covers base of chela. Chela as long as merus, 1.6 times as long as broad, with fingers occupying distal third. Dactylus of peculiar shape, rounded on superior surface and rounded distally, with tip bearing strong, acute tooth at about 90° to fixed finger. Fixed finger broadened to meet dactylus and with tip projecting as two rounded teeth which articulate with dactylar tooth.

Second legs with ischium and merus heavy; carpus of right leg with four articles (ratio 10:1.5:1.7:2.7), that of the left with five (ratio 10:1.2:1.5:1.5:2.7).

Ischium of third legs unarmed. Merus 3.0 times as long as broad, unarmed. Carpus 0.4 as long as merus, armed with heavy terminal tooth on superior margin and small movable terminal spine on inferior margin. Propodus heavy, 5 times as long as broad, 0.8 as long as merus, armed with six slight spines on inferior margin. Dactylus biunguiculate, superior spine heavy and curved, inferior spine shorter, heavy and at about 90° to inferior margin.

Abdomen very broad, shallow, pleura expanded and second pleura bearing deposit of fat. Pleopods long and broad.

Uropods of usual form, outer bearing single distal lateral spine. Telson 5 times as long as posterior margin is broad, base 3.3 times as broad as tip; inner pair of spines of tip as long as tip is broad; dorsal spines about 0.7 as long as inner distal spines, located at 0.3 and 0.6 of the length posterior from articulation.

Nine eggs,  $0.73 \times 1.13$  mm. in diameter.

Branchial formula: 5-1-2.

Allotype not exhibiting sexual dimorphism in any character except abdomen, which is less expanded, with shorter pleura and pleopods.

DISCUSSION: This series of 15 specimens exhibits variation in a number of characteristics. In some the anterior carapace projects relatively further (Fig. 8c), the truncate portion is narrower in dorsal view and less depressed in lateral view, and the orbital projections and rostrum are more pronounced,

also the rostral carina is slightly higher but still neither strong nor sharp. In one specimen, the front of the carapace is straight, showing no vestige of either the orbital teeth or the rostrum. In general the larger specimens have the straighter front. The pterygostomial angle also varies in the amount of projection but in no case is it definitely angular.

In all specimens the eyes are fully concealed in dorsal view, but with part of the cornea visible in lateral view, as is shown in Figure 8*b*.

No great variation has been noted in the antennular peduncle. However, the superior tooth of the basicerite is stronger and more acute in some specimens and its tip may reach almost as far forward as does the stylocerite. In many the flattened portion of the scaphocerite is more reduced, and in several the lateral spine of the scaphocerite does not reach past the middle of the third antennular article. The carpocerite is always markedly longer than the antennular peduncle.

On the large cheliped the distal superior margin of the merus may project to form a slight, rounded tooth and the inferior external margin in some specimens projects slightly more than it does on the type. The tooth above the dactylar articulation may be either more or less well developed than on type. The small cheliped does not show marked variations.

All specimens except one had four articles to the carpus of the second legs, and that one, like the type, had five articles in the carpus of the one second leg remaining on the specimen.

The proportions of the telson varied somewhat, and the dorsal spinules varied from about half the length to much larger than those in the type; in one specimen the posterior pair reach almost to the tip of the telson.

In the ovigerous females the size of the eggs was relatively constant, depending upon their maturity, but the number varied from five to fifteen.

Although the number of articles of the carpus, the almost flatly truncate anterior margin of the carapace, and the exposure of the cornea of the eyes in lateral view is unlike any other species of the genus *Synalpheus*, this species has been placed in this genus for the following reasons: 1, The anterior teeth of the carapace approaches this condition in some of the species of the genus, e.g., *S. tanneri* Coutière (1909: 77). 2, The general form of the antennular and antennal peduncles of this species is definitely like other species of *Synalpheus*. 3, The pterygostomial angle of this species at least approaches the usual form for the genus. 4, The large and small chelae are like other species of the genus, both in general form and in the presence of the plunger on the dactylus of the large chela and in the absence of adhesive plaques on the propodus and dactylus. Moreover, the form of the small chela is almost identical to that of *S. pescadorensis* Coutière (1905: 887). 5, The form of the third legs is similar to other species of the genus and the form of the telson is often found in the genus. 6, The branchial formula is that of *Synalpheus*.

The essential differences, then, between this and other members of the genus are in the four articles to the carpus of the third legs—which is variable in this species and has been found to vary in other species of this genus (Coutière, 1909: 20; Banner, 1953: 29), and in the exposure of the eyes, which may be merely the result of the reduction of the anteriorly projecting portion of the carapace.

Within the genus this species appears to fall in the old "Biunguiculatus" group, now better called the Coutièrei group (Banner, 1953: 37). Within this group it is related to those with a subspatulate dactylus of the small cheliped, but it can easily be separated by the extreme reduction of the orbital teeth and rostrum, by the lateral exposure of the cornea, and by the condition of the carpus of the second legs.

The name does not refer to any "two-faced" condition but rather to variation in the num-



ber of secondary articles in the carpus of the second legs.

ALPHEUS Fabricius  
Megacheles group

*Alpheus tuthilli* (Banner)

Fig. 9

*Crangon tuthilli* Banner, Pacific Sci. 7(1): 63, fig. 19, 1953.

LOCALITY: Banner, one specimen, Saipan.

DISCUSSION: This specimen, a 16 mm. female, agrees in all characteristics with the specimen described from Hawaii except that the orbital teeth and lateral spine of the basicerite are slightly longer when compared to the rostrum.

The specimen has intact the small chela which was lost in the type specimen. In it the merus is 3 times as long as broad and 0.5 as long as the entire chela; it bears no superior spines, but the inferior internal margin bears 14 short movable spines and terminates in a small acute tooth. The ischium bears 5 similar spines. The chela is about 5 times as long as broad (the palm proper twice as long as broad), with the fingers 0.55 as long as the chela. The fingers are long and thin, only slightly curved, and have crossing tips. The

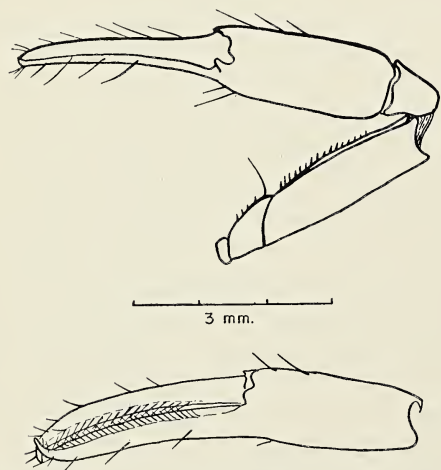


FIG. 9. *Alpheus tuthilli* (Banner). Small chela, female.

opposing faces of the fingers produced as cutting edges that are each flanked on the inner side by a regular row of short stiff setae. The chela bears only occasional long setae.

*Alpheus* species 1

LOCALITY: Banner, one specimen, Saipan.

DISCUSSION: This specimen without chelae belongs to a new species of the Megacheles group, wherein it is related to the *A. hailstonei* Coutière complex. Because the specimen is incomplete, the description and name will be deferred until a subsequent publication when a more complete specimen will be described.

*Alpheus oahuensis* (Banner)

*Crangon oahuensis* Banner, Pacific Sci. 7(1): 64, fig. 20, 1953.

LOCALITY: Banner, 2 specimens in one collection, Saipan.

DISCUSSION: These two specimens, a male and a female, differ in only two ways from the type described from shallow water in Hawaii. The lateral spine of the basicerite is longer and more acute, and the dactylus of the large chela, instead of being thin and crested in the middle and bulbous on the end, is relatively thicker in the middle and not distally expanded. The latter difference may be of significance, but inasmuch as the specimens are otherwise so similar, even to the opposing ridges of the fingers of the small chela, the specimens are assigned to this species.

*Alpheus collumianus* Stimpson

*Alpheus collumianus* Stimpson, Acad. Nat. Sci. Phila., Proc., 12: 30, 1860.

*Alpheus collumianus probabilis* subsp. nov.

Fig. 10

Three variants of this species occur in the present collections and because of the constancy of the differences exhibited are described as subspecies.

TYPES: Holotype, an ovigerous female 15

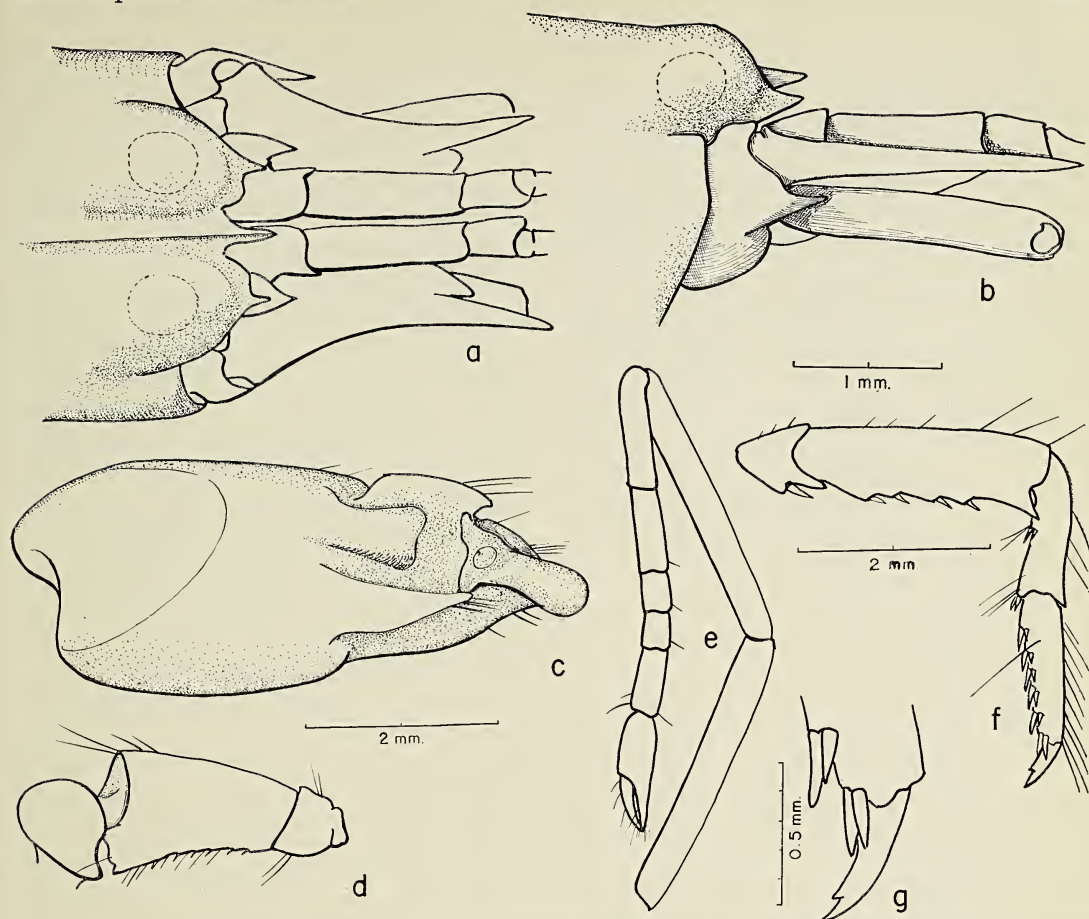


FIG. 10. *Alpheus collumianus probabilis* subsp. nov. a, b, Anterior region, dorsal and lateral aspects; c, large chela; d, large cheliped, merus; e, second leg; f, third leg; g, third leg, dactylus.

mm. long, collected by Preston E. Cloud, Jr., from Loc. C-7a, 13 May 1949. Paratypes: 1 specimen each from Cloud's localities A-7 and C-7a (10 April 1949). All types to be deposited in the U. S. National Museum.

**DESCRIPTION:** Rostrum acute, short, reaching 0.7 of visible portion of first antennular article, about twice as long as broad at base; depressed in lateral view so that tip is only slightly higher than orbital teeth. Rostral carina strong, narrowly rounded, extending posteriorly to orbital hoods, but lower than orbital hoods in lateral view. Orbital hoods inflated, rounded, and bearing short acute orbital teeth. Margin of carapace between orbital teeth and rostral base dorsoventrally flattened and expanded to form extended area

in front of anteromedial portion of orbital hoods, base of rostrum demarked from this area by deep rounded indentations. Orbitorostral grooves deep but rounded, extending to posterior portion of orbital hoods.

Antennules with second article about twice as long as first and three times as long as third article, four times as long as broad. Stylocerite with well-developed spine reaching almost to end of first antennular article. Scaphocerite longer than antennular peduncle, laterally strongly concave, squamous portion reduced, reaching only to end of second antennular article. Carpocerite as long as antennular peduncle. Basicerite with strong lateral spine, tip reaching beyond end of first antennular article.



Large chela heavy, compressed, 2.4 times as long as broad, with dactylus slightly over 0.2 as long as the entire chela. Superior crest distal to transverse groove strong, narrow, ending in a strong tooth, proximal to transverse groove indistinct. Plaque crest heavy and rounded; superior and palmar grooves deep and distinct on distal third of face of palm. Inferior depression deep and sharply delimited; shoulder rounded. (For explanation of terms see Banner, 1953, fig. 17e.) Chela bearing scattered setae. Carpus of usual form. Merus 0.3 as long as chela, 1.4 times as long as internal face is broad at point of maximum width; inferior internal margin bearing six short strong spines and terminating distally in strong acute tooth.

Small chela lacking in all specimens.

Carpal articles of second leg with ratio: 10:8:4:4:6.

Third legs with ischium bearing strong movable spine; merus 3.3 times as long as broad, with inferior margin bearing four strong spines and terminating distally in strong acute tooth; carpus about 0.5 as long as merus, bearing pair of short spines on middle of inferior margin and another pair on inferior distal angle; propodus 0.7 as long as merus, bearing six pairs of short strong spines on inferior margin (including the terminal spines); dactylus biunguiculate, with inferior unguis about 0.3 as long as and smaller at base than distal unguis. Appendage bearing scattered setae.

Telson 2.0 times as broad at base as at tip, 3.3 times as long as tip is broad, with lateral margins almost straight and anterior pair of dorsal spines located at half distance from base to tip.

DISCUSSION: See under *A. collumianus inermis*, below.

*A. collumianus medius* subsp. nov.

Fig. 11

*Crangon collumiana* Banner, 1953, Pacific Sci. 7(1): 67, fig. 21.

TYPES: Holotype, a 19 mm. male, collected by A. H. Banner. Paratypes: Banner, 7 specimens from 4 collections. Cloud, 1 specimen at A-7, 3 at D-6, 1 at E-8, 8 at Loc. 6, 1 at Loc. 8.

DESCRIPTION: Rostrum acute, short, reaching half the length of visible portion of first antennular article, about as long as broad at base, only slightly depressed in lateral view. Rostral carina high but broadly rounded, reaching posteriorly to middle of orbital hoods, only slightly lower than orbital hoods in lateral view. Orbital hoods inflated, rounded, and bearing orbital teeth somewhat shorter than rostrum. Margin of carapace between orbital teeth and rostral base dorsoventrally flattened and expanded; base of rostrum demarked from this area by prominent but shallow indentation. Orbitorostral grooves anteriorly deep but disappearing at level of posterior portion of eyes.

Antennular peduncle with second article about 1.5 times as long as first article, 2.0 times as long as third, and 3 times as long as broad, otherwise similar to *A. collumianus probabilis*. Stylocerite also similar, but with spine less pronounced. Basicerite, carpcerite, and scaphocerite as described for *A. c. probabilis*.

Large chela as described for *A. c. probabilis*. Merus 0.2 as long as chela, 1.3 times as long as internal face is broad, inferior internal margin bearing only setae, and terminating in a strong but rounded tooth.

Small chela of male 0.7 as long as large chela, 3.0 times as long as broad, with the curved heavy fingers occupying 0.55 length of chela and somewhat expanded laterally; superior crest present and terminating distally in strong tooth, proximally at transverse groove; palmar crest and associated grooves poorly demarked; shoulder rounded. Carpus with short blunt tooth projecting over base of palm. Merus almost half as long as chela, 2.2 times as long as outer face is broad; inferior internal margin armed only with light setae and terminating in a low rounded lobe. Small chela of female very similar to that of

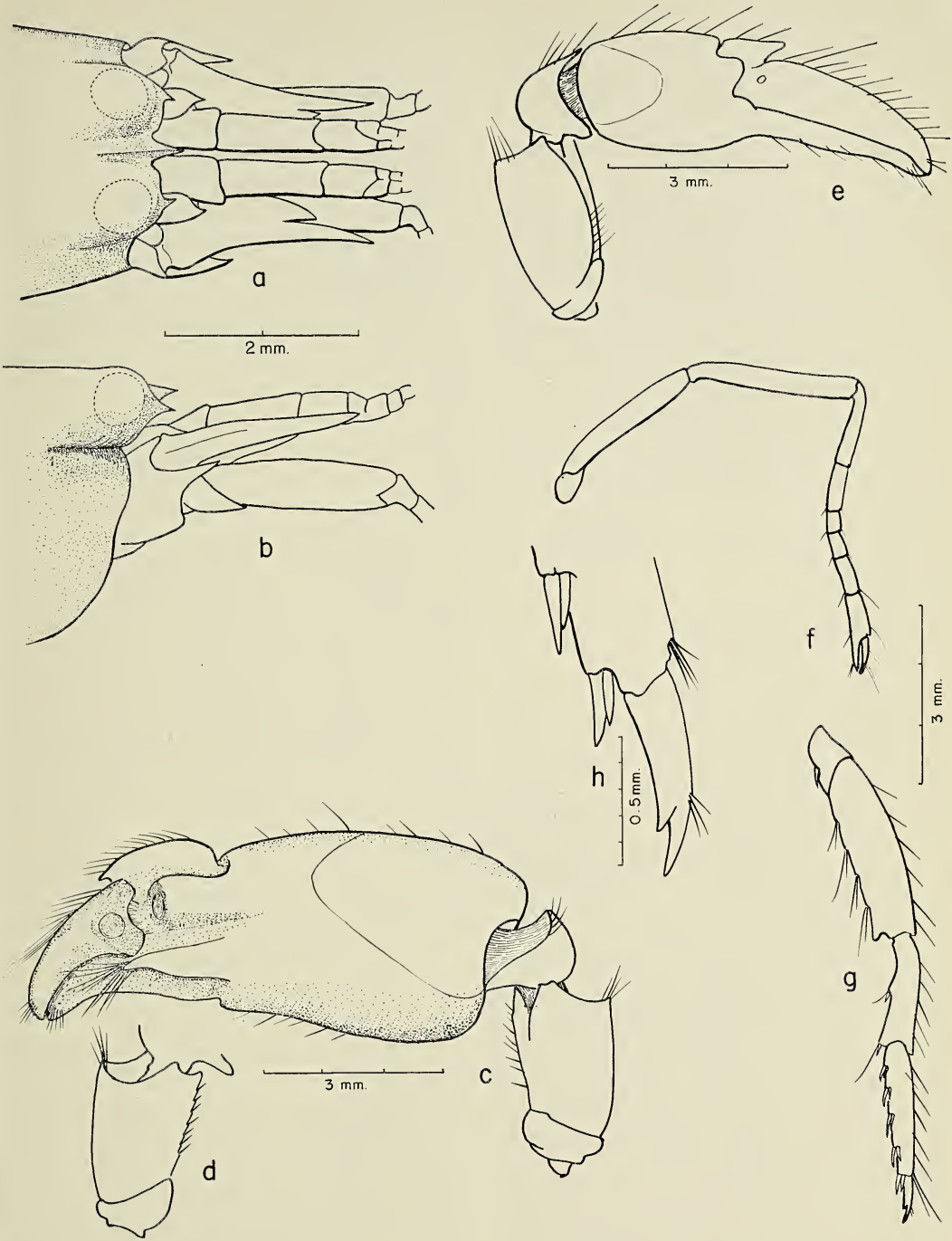


FIG. 11. *Alpheidus collumianus medius* subsp. nov. *a, b*, Anterior region, dorsal and lateral aspects; *c*, large cheliped; *d*, large cheliped, merus, medial side; *e*, small cheliped; *f*, second leg; *g*, third leg; *h*, third leg, dactylus.



male, except somewhat smaller in proportion to large chela, with sculpturing of palm proximal to dactylar articulation less pronounced and dactylus without basal expansion, instead rounded.

Carpal articles of second legs with ratio: 10:8:3:4:5.

Third legs similar to *A. c. probabilis* except that merus is 3.6 times as long as broad, bears setae instead of movable spines on inferior margin, and margin terminates in rounded tooth; distal articles are correspondingly more slender and spines slightly smaller; lower unguis of dactylus slightly larger.

Telson 2.0 times as broad at base as at tip, 2.8 times as long as broad at tip, with anterior pair of dorsal spines slightly anterior to middle.

DISCUSSION: See under *A. collumianus inermis*, below.

*A. collumianus inermis* subsp. nov.

Fig. 12

TYPES: Holotype, a male 16 mm. long, collected by Preston E. Cloud, Jr. *et al.* from locality D-7. Paratypes: Cloud, 1 specimen at Loc. D-6, 2 specimens from Loc. D-7. Types to be deposited in the U. S. National Museum.

DESCRIPTION: Rostrum short, acute, reaching a little past middle of visible portion of the first antennular article, about as long as broad at the base, tip depressed in lateral view, no higher than front of orbital hoods. Rostral carina only slightly lower than orbital hoods, depressed towards tip, rounded and terminating before middle of eyes. Orbital hoods inflated, rounded, not bearing any teeth in type, but in other specimens bearing very slight acute teeth. Margin of carapace between orbital hoods and rostral base flattened but not extended; base of rostrum demarcated by only very slight broadly rounded indentation. Orbitorostral grooves rather shallow and rounded.

Antennules with second article about 2.0 times as long as first and third articles, 2.5 times as long as broad. Spine of stylocerite

much reduced. Carpocerite and scaphocerite as in *A. collumianus probabilis*; lateral margin of basicerite projecting almost at approximately 90°.

Large chela 2.5 times as long as broad, fingers occupying 0.25 total length; otherwise like *A. c. probabilis*. Merus 0.27 as long as chela, 1.8 times as long as broad, with inferior internal margin armed with setae and terminating in small rounded shoulder.

Small chela (loose in vial, either from type or from 16 mm. female) almost 0.6 as long as large chela, 3.4 times as long as broad, with fingers occupying 0.4 entire length. Sculpturing on palm not marked, but superior crest strong distally and terminating in strong acute tooth. Merus 0.6 as long as chela, 2.3 times as long as broad, with inferior internal margin unarmed.

Carpal articles of second legs with ratio: 10:9:4:4:7.

Third legs with ischium bearing strong spine; merus 3.7 times as long as broad, inferior margin unarmed except for rounded tooth distally; carpus and propodus similar to *A. c. probabilis* except carpus bears neither middle nor terminal spines, and propodal spines are smaller; dactylus with inferior unguis strongly reduced.

Telson similar in form to *A. c. probabilis*, but 2.5 times as broad anteriorly as posteriorly, 3.5 times as long as posterior margin is broad, and with anterior pair of dorsal spinules located 0.4 of length posterior to articulation.

DISCUSSION: The three groups of specimens described above as three subspecies are obviously related. When the inherent minor individual variations are allowed for, they are similar in form of the orbital hoods proper, the antennules and antennae (save for the basicerite and the stylocerite in the last subspecies), in the form of the large chela, in the ratios of the carpal articles of the second legs, in the spiny propodi and biunguiculate dactyli of the third legs, and in the general form of the telsons.

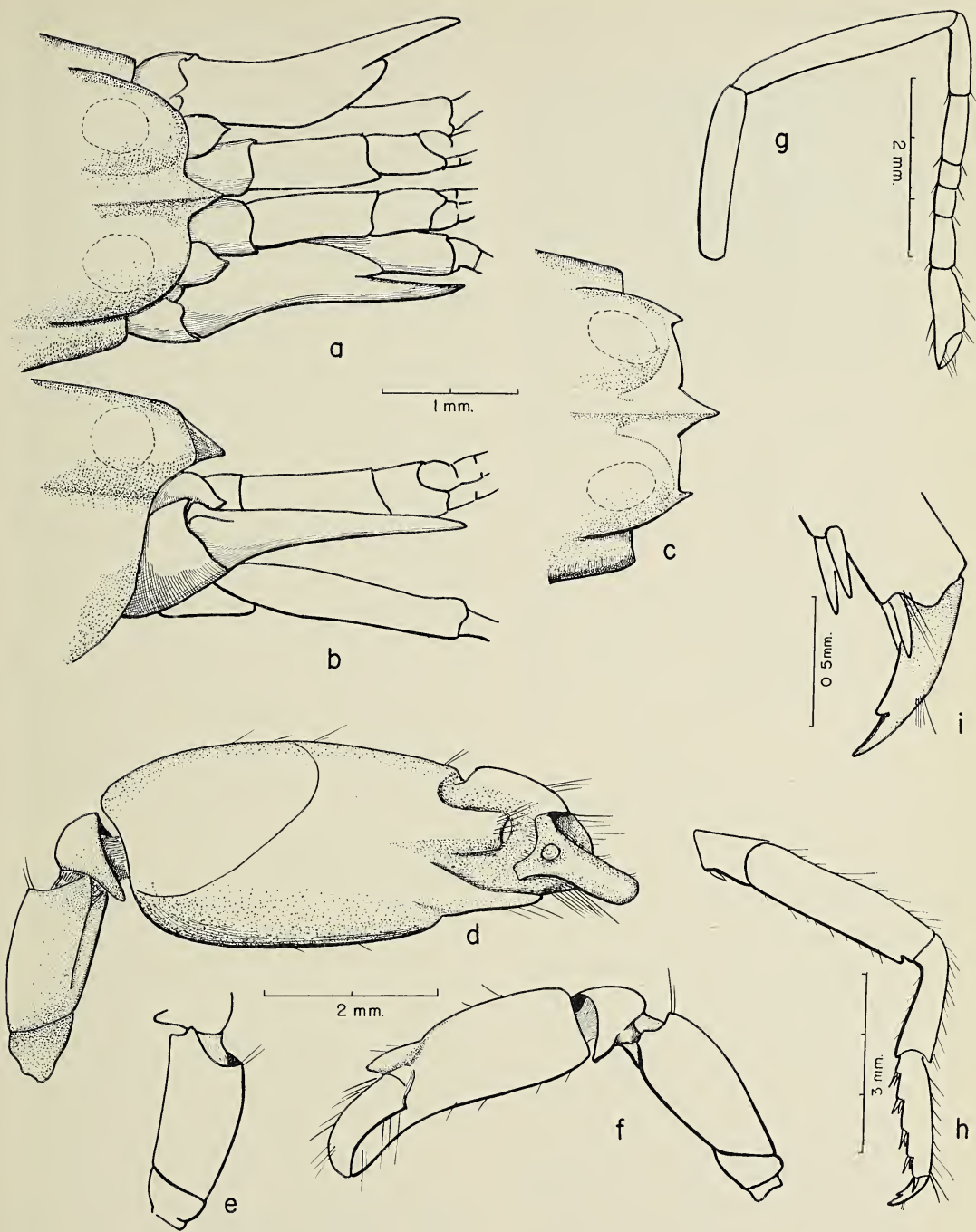


FIG. 12. *Alpheus collumianus inermis* subsp. nov. *a, b*, Anterior region, dorsal and lateral aspects (type); *c*, anterior region (paratype); *d*, large cheliped; *e*, large cheliped, merus, medial aspect; *f*, small cheliped; *g*, second leg; *h*, third leg; *i*, third leg, dactylus.



They differ, however, in the following points:

1. The orbitorostral front. This can best be understood by comparing Figures 10*a*, 11*a*, 12*a*. It should be noted that in three of the four specimens of *A. c. inermis* there are very short orbital teeth, and that *A. c. medius* can be considered a very logical intermediate between the other forms.

2. The stylocerite. Again *A. c. medius* is intermediate between the strong spine of *A. c. probabilis* and the very small spine of *A. c. inermis*.

3. The basicerite. In both *A. c. probabilis* and *A. c. medius* the lateral angle is produced into a strong tooth whereas in *A. c. inermis* it varies from a rounded right angle to a slightly acute angle.

4. The merus of the third legs. *A. c. probabilis* bears four spines and a very strong terminal tooth, *A. c. medius* bears strong bristles corresponding to the spines, and rounded and weaker tooth, and *A. c. inermis* bears scattered weak bristles and a small rounded tooth.

5. The carpus of the third legs. *A. c. probabilis* and *A. c. medius* bear both middle and distal inferior spines (although *A. c. medius* may often lack the middle spines), and *A. c. inermis* bears no spines.

Differences in the proportions of the antennules, antennae, large and small chelae, second and third legs, and telsons probably would not be found to be very significant if larger populations were measured.

In view of the striking similarities yet pronounced differences, it was difficult to decide whether these should be described as separate species or subspecies. There is no way of determining from the specimens and data at hand whether they represent separate ecological groups that would interbreed freely if mixed, or separate co-mingling species that cannot or will not interbreed; however, there is some indication from the collection data that they are separated ecologically, and their

similarities lead me to believe they are merely subspecies.

Without Stimpson's type for comparison—and as far as I have been able to determine, Stimpson's type for this species has been lost like his types for the other alpheidids he described—it is difficult to decide which of these, if any, is similar to the specimen for which he gave such a short diagnosis. However, he did state about the third legs, "mero lato, inferne spinuloso et apicem unidentato," which could be applied only to the form described above as *A. collumianus probabilis*. Inasmuch as the original type came from the Bonin Islands, only about 800 miles to the north of Saipan, it is probable that this is identical with the typical subspecies, but because of the distance and the lack of specimens from the Bonins it is inadvisable to assume this to be exactly the same form as would be found there. According to the Copenhagen decisions (paragraph 35, sect. 7) "... the neotype . . . [should come] from as near as possible to that locality [from which the holotype was obtained. . . ]," so the description of this subspecies as *A. collumianus collumianus*—which would be essentially the establishment of a neotype—would be of questionable legality.

Without re-examining the specimens it is impossible to be certain to which subspecies the specimens reported by Coutière, de Man and others belong. However, as they did not remark on the differences, it is likely they were *A. collumianus probabilis* (or *A. c. collumianus*). The specimens reported from the Hawaiian Islands by Edmondson and myself definitely belong to *A. c. medius*.

### *Alpheus deuteropus* Hilgendorf

*Alpheus deuteropus* Hilgendorf, K. Akad. Wiss. Berlin, Monatsber. 1878: 834.  
*Crangon deuteropus* Banner, Pacific Sci. 7(1): 70, fig. 22, 1953.

LOCALITIES: Banner, 1 specimen; Cloud, Loc. 8, 4 specimens. These specimens agree

almost perfectly with the specimens from Hawaii if the range of variation there is considered.

#### Macrochirus group

##### *Alpheus gracilis* var. *simplex* (Banner)

*Alpheus gracilis* Heller, K. Akad. Wiss. Wien, Sitzungber. 44: 271, Taf. 3, figs. 19–20, 1861.

*Crangon gracilis* var. *simplex*, Banner, Pacific Sci. 7(1): 75, fig. 25, 1953.

LOCALITY: Banner, 4 specimens from one collection, Saipan.

DISCUSSION: These four specimens agree well with the form described from Hawaii with two exceptions: the dorsal carina, which is lacking in the Hawaiian form and present between the orbital hoods in the typical subspecies, is present but only as a low and obtusely angular ridge in these specimens (it is not delimited, however, by the deep orbitorostral furrows which are found in the typical form); the inferior convexity of the dactylus of the third legs of the Hawaiian form is here developed as a low but flattened protuberance with proximally and distally rounded margins.

Three of the specimens have black spines on the uropods; in the fourth the spines are dark brown.

##### *Alpheus edmondsoni* (Banner)

*Crangon edmondsoni* Banner, Pacific Sci. 7(1): 78, fig. 26, 1953.

LOCALITY: Banner, 2 specimens from one collection, Saipan.

These specimens fall well within the range of variation noted in Hawaii.

##### *Alpheus ventrosus* Milne-Edwards

*Alpheus ventrosus* Milne-Edwards, Histoire Naturelle des Crustacés, 2: 352, 1837.

*Alpheus laevis* Randall, Acad. Nat. Sci. Phila., Jour. 8(1): 141, 1839.

*Alpheus obesomanus* Boone, Vanderbilt Mar. Mus., Bul. 6: 135, 1935 [partim].

*Crangon ventrosa* Banner, Pacific Sci. 7(1): 84, fig. 28, 1953.

LOCALITIES: Banner, 2 specimens in one collection; Cloud, Locs. 6, 8, 9, one specimen each.

DISCUSSION: Two variations are noted in these specimens. First, in several of the smaller specimens, especially in a 15 mm. ovigerous female from Cloud's locality 9, the inter-orbital continuation of the rostrum is high and narrow, almost a rounded carina, instead of flat and broad across the top. In this respect these specimens resemble *A. latipes* (Banner) more closely than they do *A. ventrosus*.

In the two specimens of my own collection, the external spines of the uropods in the 16 mm. female are light brown, and in the accompanying 15 mm. male they are dark brown, almost black. Such dark spines are found in the Macrochirus group and this is often used as a specific characteristic but it has not been remarked upon before in this species.

##### *Alpheus nanus* (Banner)

*Crangon nanus* Banner, Pacific Sci. 7(1): 90, figs. 30, 31, 1953.

LOCALITIES: Banner, 8 specimens in 3 collections; Cloud, locality D-6, 2 specimens.

DISCUSSION: These specimens agree perfectly with those from Hawaii except that about half of these bear up to six weak spinules or short bristles on the inferior internal margins of the meri of the large and small chelipeds.

##### *Alpheus paragracilis* (Coutière)

*Alpheus paragracilis* Coutière, Paris Mus. d'Hist. Nat., Bul. 3(7): 304, 1897b.

*Crangon paragracilis* Banner, Pacific Sci. 7(1): 96, fig. 33, 1953.

LOCALITY: Cloud, Loc. 6, 2 specimens.

These specimens agree well with those described from Hawaii.



## Obesomanus subgroup

*Alpheus microstylus* (Bate)

*Betaeus microstylus* Bate, Challenger Repts. 24: 566, pl. 101, fig. 6, 1888.

*Alpheus obesomanus* de Man, Arch. Naturg. 53: 520, 1888; Abhandl. Senckenb. Naturf. Gesells. 25: 867-869, 1902.

*Alpheus malleodigitus* Coutière, Les Alpheidae, p. 223, 316 (figs. 270-272, 400) 1899 [nec *A. malleodigitus* (Bate)].

*Alpheus microstylus* Coutière, Fauna and Geog. Mald. and Laccad. 2: 884, pl. 76, fig. 23, 1905.

LOCALITIES: Banner, 5 specimens in one collection; Cloud, 15 specimens at locality A-5, 4 at FX.

DISCUSSION: The few specimens of this species exhibit some interesting variations. The scale of the antenna is usually similar to that depicted by Coutière (1905) but in several specimens it is shortened, and in one the squamous portion is so reduced that it does not reach to the end of the second antennular article. The merus of the large chela usually bears an obtuse tooth distally on the inner inferior margin, but in some specimens this tooth is acute, and in one small specimen it is reduced to a slight rounded eminence. The ratio of the first two articles of the carpus of the second legs varies from slightly less than 1:3 to more than 1:4. Finally, the propodus of the third legs is armed with five to seven spines instead of only five, as described by Coutière.

*Alpheus lutini* Coutière

*Alpheus lutini* Coutière, Fauna and Geog. Mald. and Laccad., 2: 885, pl. 76, fig. 24, 1905; de Man 1911, Siboga Exped. 39a<sup>1</sup>: 346, pl. 14, fig. 69 [additional description].

LOCALITIES: Banner, 65 specimens in 8 collections; Cloud, 2 specimens at localities A-7, 3 at C-1, 1 at C-7a (13 May 1949), 6 at D-5.

DISCUSSION: This species is more variable than has been indicated previously, and shows

variation in most of the structures commonly measured. For example, the squamous portion of the scaphocerite, while always poorly developed, may be twice as large in some specimens as in others; the lateral spine of the scaphocerite may equal the antennular peduncle in length, or it may reach only slightly beyond the end of the second antennular article (in one specimen the spine of the left scale reached to the end of the second antennular article, whereas the right reached only to the middle of the same article). Coutière stated that the second legs were 3 times as long as the carapace, whereas in these specimens they vary from about 2 times to more than 3.5 times as long. Similar variations in proportions occur in the chelae and in the third legs.

Except for these variations these specimens agree very well with Coutière's description. At times however, this variation caused difficulty in the use of de Man's key (1911), for while de Man stated that the small chela was less than 3.0 times the length of the fingers (Coutière's ratio was 2.5), it was actually found to be as much as 3.2 times this length.

*Alpheus phrygianus* Coutière

*Alpheus phrygianus* Coutière, Fauna and Geog. Mald. and Laccad. 2: 886, pl. 77, fig. 25, 1905.

LOCALITIES: Banner, 2 specimens in one collection; Cloud, 3 specimens at locality A-5, 2 at A-7, 2 at C-1, 3 and 4 at C-7 on 4 April and 13 May 1949, respectively, 2 at D-5, 2 at D-8, 2 at E-7.

DISCUSSION: This species is abundant in the Saipan collections, but few of the specimens are intact, probably in part because most of the specimens died with the long thoracic legs outspread.

In general the specimens agree with Coutière's description of specimens from the Indian Ocean; however, far greater variation is seen in these specimens than was noted by Coutière for his four specimens.

In the younger specimens (less than 10 mm. long) the antennular peduncle is shorter, especially the second article. In the antenna, the spine on the scaphocerite varies from about two-thirds the length of the second antennular article (on an 8 mm. specimen) to less than one-third its length on mature specimens; the squamous portion in some specimens is as depicted by Coutière, arising abruptly at slightly more than half of the length of the outer spine, but in others it tapers gradually to near the tip of the spine, with most of the specimens intermediate in condition; in most the squamous portion is without setae as described by Coutière, but in a few there are some short feeble bristles along its margin; finally, the antennal peduncle varies from reaching the tip of the second antennular article to reaching only two-thirds its length. The large chela does not exhibit any marked variation. In the small chela most of the specimens have fingers more nearly 1.3 times the length of the palm than 1.0 as in the type specimen. Coutière remarked that the second leg varies from 2.2 to 4 times the length of the carapace; in a few of these specimens the second legs are almost 5 times the length of the carapace. On the third leg the spine on the inferior distal margin of the merus usually is small and subacute like that depicted by Coutière, but in several it is strong and acute, and in one it is reduced to a rounded protuberance; on the propodus there are usually seven instead of five spines. The telson usually approaches the proportions given by Coutière, but in some the tip is relatively broader so the length is only 3.2 times the breadth of the tip instead of 4.5. These variations do not appear to be consistent enough to be of taxonomic importance.

*Alpheus perplexus* sp. nov.

Fig. 13

(?) *Alpheus* species, de Man, Siboga Exped. 39a<sup>1</sup> (2): 349, pl. 15, fig. 71, 1911.

TYPES: Holotype, an 18.8 mm. male col-

lected by Preston E. Cloud, Jr., from locality A-7; allotype, an ovigerous female 20.4 mm. long, same location. Types to be deposited in the U. S. National Museum.

DESCRIPTION: Front of carapace straight (in type) to concave (in allotype); orbital hoods somewhat inflated and rounded; interorbital carina slight and rounded, not reaching to anterior margin of carapace or posterior to end of orbital hoods.

Second antennular article 2.1 times as long as visible portion of first, 2.3 times as long as third, and 3.3 times as long as broad. Stylocerite rounded. Scaphocerite reaching slightly beyond end of second antennular article; carpocerite reaching almost to end of third antennular article; basicerite unarmed.

Large chela of type specimen heavy, 2.8 times as long as broad, flattened, and with fingers occupying 0.2 of entire length. Only distal third of chela sculptured; superior crest interrupted by deep, abrupt transverse groove, distal to transverse groove crest thin, high, terminating in a rounded shoulder. Plaque crest heavy, rounded, separated from superior and inferior crest by deep grooves. Inferior crest pronounced, distally high and thin, terminating in a rounded shoulder flanking dactylus. Inferior shoulder rounded. Fixed finger very short, distally notched to receive dactylus. Dactylus closing almost across end of palm, heavy, rounded, nearly hammer-shape. Merus 0.3 as long as chela, 3.1 times as long as broad, without teeth or spines, with inferior external margin rounded.

Large chela of female of similar armature, but relatively much smaller than that of male, 3.9 times as long as broad.

Small chela lacking in male; in female chela 4.5 times as long as broad, with heavy fingers occupying distal 0.3; small tooth projects superior to articulation at approximately 90°.

Second legs long, strong, with merus about 0.7 as long as large chela in type. Carpal articles with ratio: 10:11:3:4:5.

Third legs with ischium armed with rather weak spine; merus almost 4 times as long as



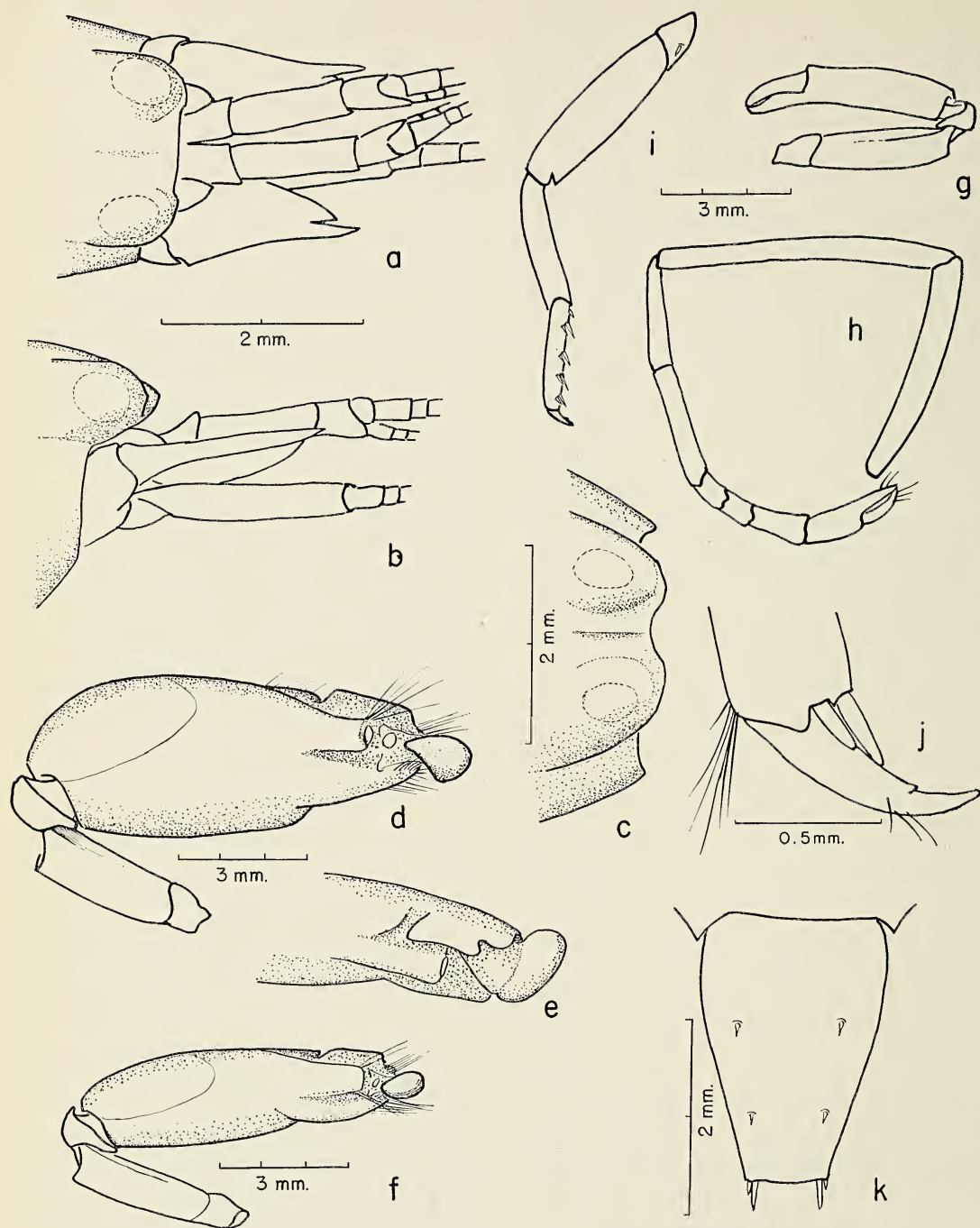


FIG. 13. *Alpheus perplexus* sp. nov. *a, b*, Anterior region, dorsal and lateral aspects, type specimen; *c*, anterior region, dorsal aspect, allotype (specimen asymmetrical); *d, e*, large cheliped, lateral and superior aspects, type specimen; *f*, large cheliped, allotype; *g*, small cheliped, allotype; *h*, second leg; *i*, third leg; *j*, third leg, dactylus; *k*, telson.

broad, armed with weak sub-acute tooth distally; carpus 0.7 as long as merus, unarmed except for two rounded projections distally; propodus 0.6 as long as merus, armed with one single and five pairs of spines on inferior margin; dactylus curved, with very slight secondary tooth (on female secondary tooth somewhat larger).

Telson 3.3 times as long as posterior margin is broad, 2.3 times as wide anteriorly as posteriorly; sides slightly rounded, both pairs of dorsal spinules small, anterior pair 0.4, posterior pair 0.7 length of telson posterior to articulation. Inner uropod with several weak spinules on outer distal margin.

DISCUSSION: This species is difficult to assign to an infrageneric group, for the anterior carapace and second legs are very much like those found in the *Obesomanus* group, but the large chela is more like those found in the *Macrochirus* group. The dactylus of the large chela, which should be hammer-shaped in the *Obesomanus* group, is intermediate between the form found in many species of the *Megacheles* and *Macrochirus* groups and those found in the *Obesomanus* group.

Only on the basis of the lack of a rostrum and of orbital teeth was this species assigned to this group. Within the group it is definitely separated from all other named species by the form of the large chela and by the fact that the dactyli of the third and fourth legs carry a small secondary unguis.

The species appears to be similar to the specimen that de Man briefly described but left unnamed because it lacked both of the chelae and the second legs. Between the two specimens there are differences in proportions of the antennules, antennae, third legs and telson, but these differences are slight and probably not significant. Also de Man's specimen had a slight rostrum with the interorbital carina reaching to its tip, while neither of these specimens show a trace of the rostrum, and the interorbital carina terminates posteriorly to the margin of the carapace. This too, in view of the fact that the two specimens available

show some variation, and that marked variation has been reported for species showing a similar frontal region, may be without significance. The armature and general form of the 3rd legs are similar. (De Man described the stylocerite as acute, but figured it as similar to those of these specimens.)

The difference between the form of the large chela in the male and the female is interesting. While in most species the chela of the female is considerably smaller than that of the male, it is seldom that the proportions are so pronouncedly different. It is possible, of course, that these specimens represent two species, but as they are similar in other characteristics, as they bear similar sculpturing on the large chela, and as they were collected together at the same station, it seems unlikely that they are other than a single dimorphic species.

*Alpheus chamorro* sp. nov.

Fig. 14

TYPE: Holotype, a 7.5 mm. male collected by A. H. Banner. Specimen to be deposited in U. S. National Museum.

DESCRIPTION: Anterior margin of carapace projecting beyond orbital hoods as narrow, somewhat flattened shelf; rostrum small, tip rounded; rostral carina low but sharp, extending from behind orbital hoods to tip of rostrum. Orbital hoods inflated, rounded, and anteriorly set off by medial flat orbitocarinal area.

Second antennular article 1.7 times as long as broad; first and third articles subequal in length and 0.7 as long as second article; stylocerite short, anteriorly acute. Basicerite unarmed. Scaphocerite with heavy lateral spine reaching to end of third antennular article, with reduced squamous portion reaching to end of second article. Carpocerite longer than antennular peduncle.

Large chela round, inflated, 2.6 times as long as broad and 2.2 times as long as high (*i.e.*, when the dactylus is seen in profile), fingers occupying the distal 0.25. In profile,



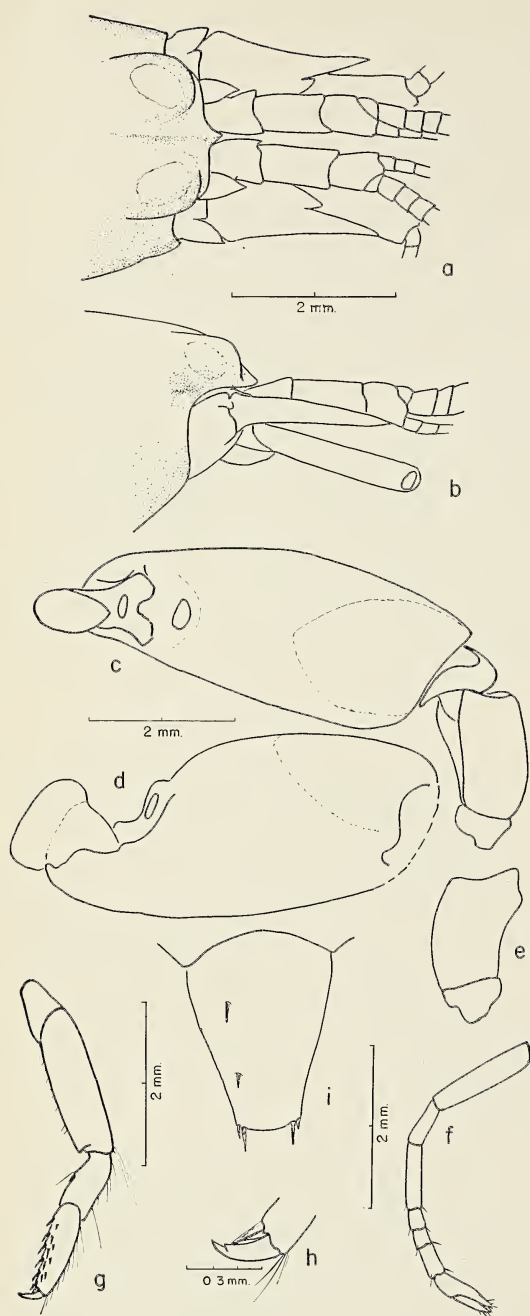


FIG. 14. *Alpheus chamorro* sp. nov. a, b, Anterior region, dorsal and lateral aspects; c, d, large cheliped, lateral and inferior aspects; e, merus, large cheliped, medial aspect; f, second leg; g, third leg; h, dactylus, third leg; i, telson (dorsal spinules lacking in specimen).

chela slopes abruptly toward articulation of dactylus; palmar adhesive plaque borne upon rounded eminence protruding from slope. Fixed finger short, cleft to accommodate dactylus. Dactylus short, heavy, but not as strongly hammer-shaped as in some other members of the group. Merus short, heavy, 0.4 as long as chela, outer face 1.4 times as long as broad; inferior internal margin bearing heavy rounded protuberance but otherwise unarmed.

Small chela lacking in specimen.

Carpal articles of second legs with ratio: 10:14.7:4.7:4.0:7.3.

Ischium of third legs unarmed. Merus 3.3 times as long as broad, bearing rounded tooth of moderate development on inferior distal margin. Carpus heavy, 1.6 times as long as broad, 0.35 as long as merus, armed with short heavy spine in middle of inferior margin and distally with two heavy subacute projections. Propodus correspondingly heavy, 0.6 as long as merus, armed with six pairs of spines along inferior and inferodistal margins, with scattered smaller spines adjacent. Dactylus strongly curved bearing small secondary unguis that is difficult to discern.

Uropods of usual form. Telson short, broad and abruptly tapering, 3.1 times as long as distal margin is broad, 2.3 times as wide proximally as distally; dorsal spinules well developed on left side only, anterior spinule 0.3, posterior 0.7 of length posterior to articulation.

**DISCUSSION:** While the general form, even to the shape of the anterior carapace and the secondary unguis on the dactylus of the third legs is very reminiscent of *A. paralcione* (Coutière) of the *Crinitus* subgroup, the hammer-shaped dactylus of the chela of this species shows that it definitely belongs to the *Obesomanus* subgroup.

Unlike all species of the *Obesomanus* subgroup except *A. perplexus* Banner (above) and, if distinct, *A. species de Man* (1911: 349), *A. chamorro* has a biunguiculate dactylus on the third legs.

This species can be distinguished easily from *A. perplexus* by the form of the large chela, which is rounded in this species but bears deep sculpturing in *A. perplexus*.

The comparison of this species, *A. perplexus* and de Man's *A. species* shows the difficulty of trying to identify an incomplete specimen, for although the chelae show that *chamorro* and *perplexus* are not even closely related, each is similar enough to de Man's description of his broken specimen to be confused with it. *A. chamorro* is quite like de Man's specimen in the configuration of the anterior carapace and the bases of the antennae and antennules, but dissimilar in the structure of the third legs; *A. perplexus* is less like de Man's specimen in the anterior carapace but more similar in the third legs. After careful consideration it appears that the legs are more constant in their character than the anterior carapace, so de Man's specimen has been assigned, but still with doubts, to *A. perplexus*.

It should also be noted that *A. chamorro* shows affinity to *A. bradypus* Coutière (1906: 891) in the *Crinitus* group. While there are

specific characteristics adequate to separate them easily, such as the dactylus of the third legs and the slight proximal projection of the "head" of the dactylus of the large chela, in general configuration the two species are strikingly similar, even to the shape of the eminence that bears the palmar adhesive plaque and the rounded protuberance on the inferior internal margin of the large chela. While the two species may merely show convergent evolution, or may be closely related on the limits of their respective groups, this may also indicate that the groups were separated upon artificial criteria.

The specific name has reference to the Chamorro people, the original inhabitants of the Mariana Islands.

Alpheus species 2  
Fig. 15

SPECIMEN: A 11.2 mm. female, nonovigerous, collected by A. H. Banner.

DESCRIPTION: Anterior carapace without trace of rostrum, rostral carina, or orbito-rostral furrows but uniformly inflated and rounded over eyes.

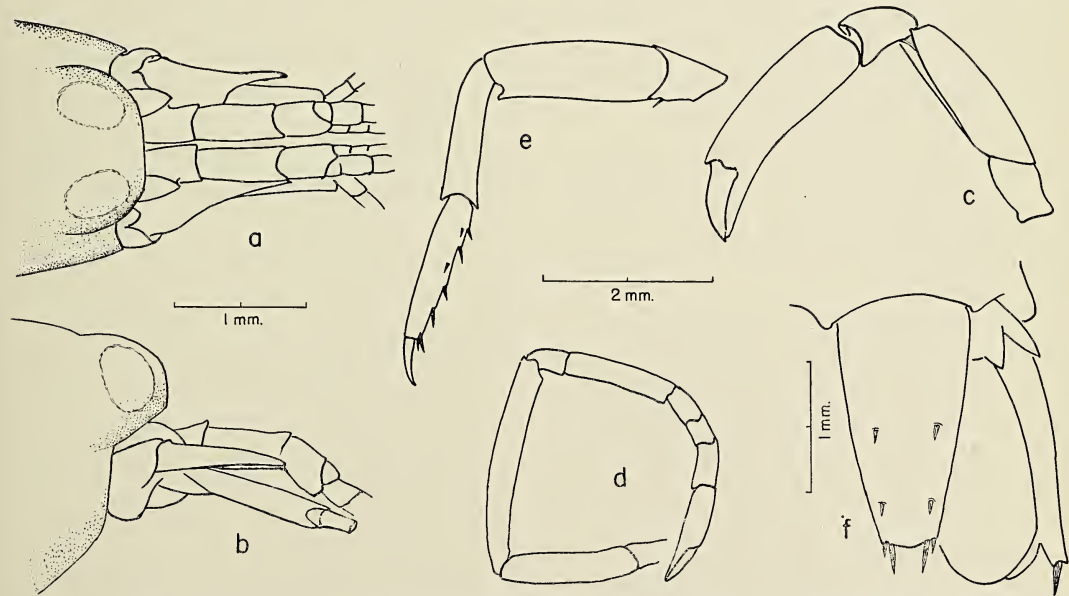


FIG. 15. *Alpheus* species 2. a, b, Anterior region, dorsal and lateral aspects; c, small cheliped; d, second leg; e, third leg; f, telson and uropods.



Antennular peduncle with second article 2.5 times as long as broad, 1.7 times as long as visible portion of first and third article which are subequal. Stylocerite without lateral spine, rounded, reaching half length of basal article. Upper flagellum slightly shorter than peduncle, lower shorter than upper. Basicerite unarmed. Lateral spine of scaphocerite reaching to end of second antennular article; flattened portion reduced, narrow, reaching only to first third of second antennular article. Carpocerite approximately as long as antennular peduncle. Flagellum of usual form.

Large chela lacking. Small chela rounded, regular, slightly curved toward fingers, 4.0 times as long as broad, with fingers occupying distal 0.3. Carpus somewhat elongate. Merus unarmed, outer face 3.6 times as long as broad, 0.7 as long as chela.

Carpal articles of second legs with ratio: 10:30:8:7:13.

Ischium of third legs bearing reduced spine. Merus 4.1 times as long as broad, distal inferior margin bearing tooth of moderate size. Carpus 0.66 as long as merus, distally produced into superior and inferior acute teeth of moderate size. Propodus 0.83 as long as merus, bearing eight spines irregularly placed on inferior and distal margins. Dactylus simple, curved, 0.26 as long as merus.

Telson 2.8 times as long as posterior margin is wide; anteriorly 1.5 times as wide as posteriorly; margins very slightly convex. Uropods of normal form; distal spine of outer uropod not black.

DISCUSSION: Without the large chela on this specimen, it is impossible to assign it even to group. The reduction of the orbital teeth and the reduction of the scaphocerite together with the armature of the third legs, would indicate that it may belong to the *Obesomanus* group, but, without knowing whether the dactylus of the large chela is hammer-shaped or not, it cannot be assigned for certain. Certainly the unique character of the front of the carapace does not show close

relationship to any group or to any species of the genus *Alpheus* known to me.

The form of the rostral front appears to be similar to that described by Armstrong (1949: 12) as characteristic of his new genus, *Thunor*. However, on all other characteristics for this genus—absence of the cardiac notch on the carapace, the absence of anal tubercles, the absence of an articulation in the outer uropods (the ocular beak was not examined)—this species differs from *Thunor* and resembles *Alpheus*. In view of the wide variation in the rostral front found in *Alpheus* the one similarity was not considered to be of generic importance.

Because the specimen is imperfect it has been left unnamed.

#### Crinitus subgroup

#### *Alpheus cloudi* sp. nov.

Fig. 16

TYPE: Holotype, a unique ovigerous female 17.6 mm. long, collected by Preston E. Cloud, Jr., at locality D-5. Specimen to be deposited in the U. S. National Museum.

DESCRIPTION: Body form short, heavy. Anterior portion of carapace depressed when seen in lateral view. Orbital hoods inflated, rounded, demarked from anteromedial portion of carapace and overhanging anterolateral portion. Anteromedial portion of carapace broad, flat, projecting, margins almost straight; rostrum proper poorly demarked from adjacent portions of carapace, short, broad, with tip reaching beyond middle of visible portion of first antennular article. Rostral carina low but sharp reaching posteriorly from tip of rostrum to slightly behind orbital hoods. Eyes small, not filling orbital hoods.

Second antennular article about 2 times as long as broad, 1.3 times as long as visible portion of basal article, 2.4 times as long as distal article. Stylocerite short, heavy, with acute tip reaching almost to end of first antennular article. Basicerite bearing small spine. Scaphocerite reaching to near end of

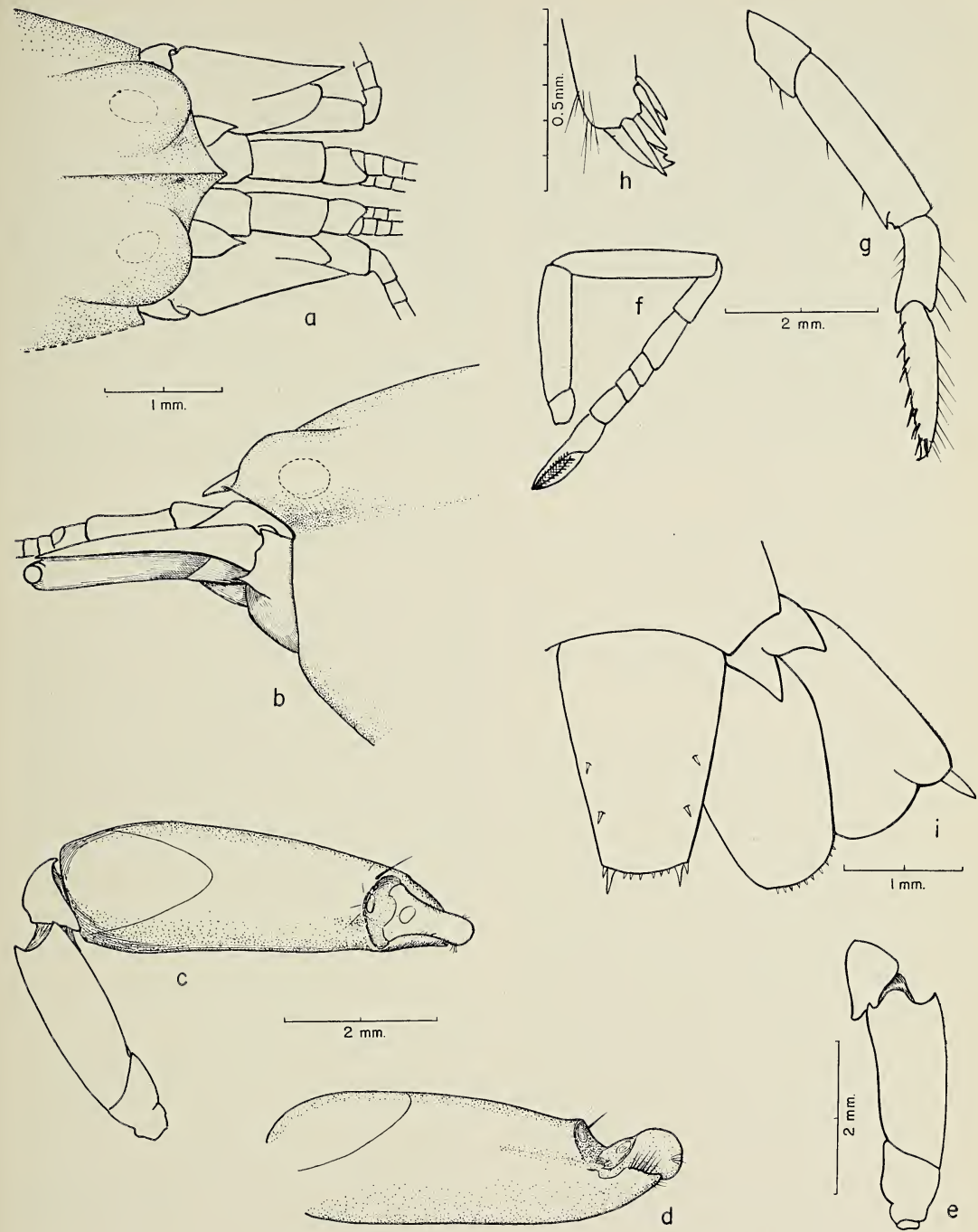


FIG. 16. *Alpheus claudi* sp. nov. *a*, Anterior region, dorsal aspect (right margin distorted in specimen but reconstructed in drawing); *b*, same, lateral aspect; *c*, large cheliped, lateral aspect; *d*, large chela, inferior aspect; *e*, large cheliped, merus, medial aspect; *f*, second leg; *g*, third leg; *h*, third leg, dactylus, posterior or lateral aspect; *i*, telson and uropod.



antennular peduncle, squamous portion reaching to end of second antennular article; outer margin almost straight. Carpocerite reaching slightly beyond end of antennular peduncle and scaphocerite.

Large chela subcylindrical, as broad as high, slightly tapering distally, 3.1 times as long as broad. Palm below and immediately proximal to adhesive plaque with slight longitudinal depression. Dactylus 0.23 as long as entire chela, somewhat crested, rounded. Chela almost devoid of setae. Merus 2.6 times as long as broad, almost 0.5 as long as chela; superior margin distally projecting as small rounded tooth; inferior internal margin terminating distally in small acute tooth that is difficult to discern.

Small chela lacking.

Second legs relatively short, heavy. Carpal articles with ratio: 10:9:3.5:3.5:5.5; first article 3 times as long as broad. Chela 1.5 times as long as first carpal article, palm occupying slightly over 0.3 the entire length; fingers arched, tips crossing, bearing stiff combs of setae that cross.

Third legs heavy, ischium unarmed. Merus 4 times as long as broad, distal inferior margin armed with tooth of moderate development.

Carpus 0.38 as long as merus, both distal margins projecting as rounded teeth. Propodus 0.7 as long as merus, strongly tapering, distally only half as broad as proximally; inferior margin bearing 11 strong acute spines. Dactylus short, partially hidden, especially in anterior or median view, by propodal spines, some of which are equal in length to dactylus; dactylus heavy, curved, bearing slight biunguiculation that is difficult to discern both because of spines and normal rotation of dactylus.

Abdomen broad, rather soft. Sixth abdominal segment without spines or teeth. Telson 2.0 times as broad anteriorly as posteriorly, 3.4 times as long as broad posteriorly; sides straight, posterior margin slightly arcuate; anterior pair of dorsal spinules 0.5, posterior pair 0.8 of distance to tip from articulation;

tip bearing about six very small spinules in addition to usual posterolateral spines. Uropods of usual form, inner bearing about 10 spinules along distolateral margin similar to those on tip of telson.

DISCUSSION: This species apparently belongs to the Crinitus subgroup in spite of the fact that the chela bears a short, shallow, longitudinal groove. Within the group it appears to be most closely related to the species *A. alcyone* de Man, *A. providencei* Coutière, *A. arethusa* de Man, and *A. paralcione* Coutière. From *A. alcyone* it may be separated by the lack of spines on the merus of the third legs as well as other characteristics. It is separated from *A. arethusa* and *A. paralcione* by a combination of characters, one of the more conspicuous being the lack of spines or teeth on the sixth abdominal segment. It appears to be somewhat related to *A. providencei*, especially in the frontal regions of the carapace, the antennular and antennal peduncles, the general form of the third leg and the trace of biunguiculation of its dactylus but it can easily be separated by the more elongate rostral triangle, the presence of a spine on the basicerite, the more elongate large chela, the armature of the merus of the cheliped, the shorter second article of the carpus of the second legs, the short dactylus of the third legs, and the form and armature of the uropods and telson.

The species was named in honor of Preston E. Cloud, Jr., U. S. Geological Survey, who collected this and many of the other specimens reported in this study.

#### *Alpheus brevipes* Stimpson

*Alpheus brevipes* Stimpson, Acad. Nat. Sci. Phila., Proc. 12: 30, 1860.

*Crangon brevipes* (Stimpson) Banner, Pacific Sci. 7(1): 103, figs. 35-37, 1953. [Neotype established.]

LOCALITIES: Banner, 2 specimens in 2 collections; Cloud, 8 specimens at Loc. D-8, 1 at Loc. 6.

DISCUSSION: These specimens, together

with the specimens from Arno, Onotoa, and Palmyra to be reported upon in later papers, parallel the variation already reported from Hawaii (Banner, 1953: 103). It should be noted under the variation of the frontal region of the carapace that only rarely were the "Orbital hoods acute in front, with their apices curved inward," a characteristic given by de Man in his key (1911: 315); instead the ridges of the orbital hoods were usually rounded, and often did not slope medially towards the ventral side.

### *Alpheus bucephalus* Coutière

*Alpheus bucephalus* Coutière, Fauna and Geog. Mald. and Laccad. 2: 890, pl. 78, fig. 29, 1905.

LOCALITIES: Banner, 12 specimens in four collections; Cloud, 3 specimens at D-5, 3 at D-8, 1 at E-4, 1 at FX.

DISCUSSION: Several of the larger male specimens which otherwise agree with the characteristics of the species have broadened fingers on the small chelae, a trait that is not supposed to occur in this species. However, as the specimens are similar to *A. bucephalus* in all other characteristics, and as they were in a mixed collection with smaller specimens without the broadened finger, they have been assigned to this species. This peculiarity will be discussed in a future paper.

### *Alpheus bradypus* Coutière

Fig. 17

*Alpheus bradypus* Coutière, Fauna and Geog. Mald. and Laccad. 2: 891, pl. 78, 79, fig. 30, 1905.

LOCALITY: Banner, 8 specimens in 1 collection, Saipan.

DISCUSSION: This group of eight specimens agree quite well with Coutière's description of his two damaged specimens. The most conspicuous differences between the two lie in the following characteristics: 1, The second antennular article is slightly longer than that

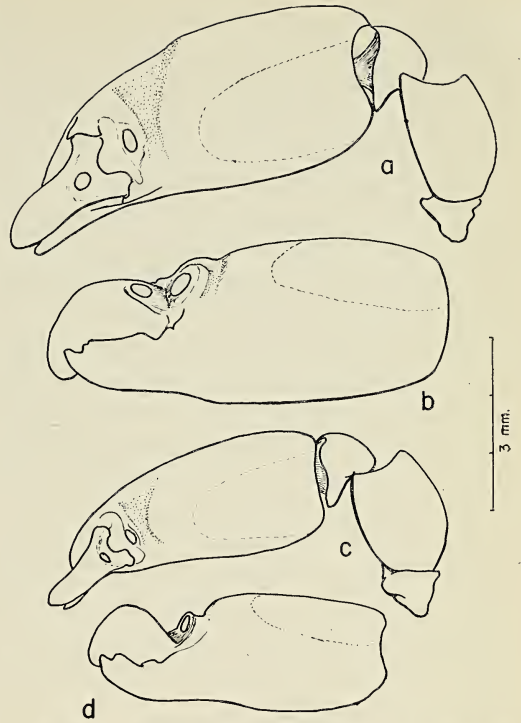


FIG. 17. *Alpheus bradypus* Coutière. a, b, large chela male; c, d, large chela, female.

described by Coutière. 2, There is a small, poorly developed and difficult to discern tooth on the basicerite, while Coutière reported his specimens as unarmed. 3, In none of the males did the dactylus of the small chela show the fringe of setae depicted by Coutière; moreover the small chelae of the males and females were more alike, showing less sexual dimorphism. 4, The internal ramus of the uropods bears a row of numerous, although poorly developed denticles along its distal margin. These differences may in part be due to individual variation, so common in related species of this group, or they may be due to geographical variation; certainly it seems inadvisable at the present state of knowledge of the species to divide it into subspecies on the basis of these characteristics.

Both of Coutière's specimens were without the large chela. As most of these specimens are complete, I have shown the chelae of a mature male and a mature female in Figure



17. These chelae are dimorphic both in size and proportions. However, in both sexes there is a poorly demarked shallow depressed area on the upper side of the chela proximal to the articulation of the finger. This depression appears slightly more distinct in the female than in the male, possibly because the chela is more slender. The merus is unarmed on all margins but the inferior internal margin projects slightly distally.

There is some variation in the proportions of the antennular peduncle. The scaphocerite in one specimen, instead of reaching slightly past the middle of the third antennular article, reaches beyond it by half its length. In the same specimen the reduced squamous portion of the scaphocerite gradually tapers to its end which is opposite the distal end of the second antennular article instead of being more abruptly truncate opposite to the middle of the same article. Otherwise this specimen is similar to the others.

#### *Alpheus eulimene* de Man

*Alpheus eulimene* de Man, Siboga Exped. 39a<sup>1</sup>  
(2): 364; pl. 16, fig. 76, 1911.

LOCALITY: Cloud, 2 specimens at C-7a, 10 April 1949.

DISCUSSION: *A. eulimene* de Man and *A. styliceps* Coutière (1905: 889, pl. 78, fig. 28) are very closely related species, separated principally by the form of the frontal portion of the carapace and by the proportions of the third leg and the armature of the fourth. The two specimens from Saipan, a 9.0 mm. female and a broken and distorted male of 7.8 mm., lie somewhat intermediate between the two species. In *A. eulimene* the front of the carapace is almost straight in front of the orbital hoods, abruptly giving rise in the middle to a very short rostrum; it bears a dorsal carina that continues posteriorly to the middle of the carapace. In *A. styliceps* the anterior margin of the carapace curves gradually into a larger rostrum, but the carina does not extend posteriorly to the orbital hoods. In these spec-

imens the rostrum is like *A. styliceps*, except that the curve is less gradual and the base of the rostrum more abrupt; the dorsal carina is like *A. eulimene*. In *A. eulimene* and in these specimens the merus of the third legs is slightly over 4 times as long as broad, while in *A. styliceps* it is only 3 times as long; in de Man's species and in these specimens the merus of the fourth leg is unarmed, while in Coutière's it bears a strong distal tooth. If the distinction between these species is maintained after more specimens are examined, then these two specimens appear to belong to de Man's species.

There are several further minor differences between these specimens and de Man's description. In the male the scaphocerites are asymmetrically developed, with that of the right being reduced as described by de Man, but that of the left better developed, with the tip of the lateral spine reaching beyond the end of the antennular peduncle and the squamous portion reaching to the middle of the third, not the second, antennular article. In the female the palm of the small chela is 1.9 times as long as broad and as long as the fingers, instead of 1.5 times as long as broad and longer than the fingers. Unfortunately the small chela is lacking in the male. De Man gives lengths for the articles of the carpus of the second leg which produce the ratio of 10:14.4 for the first two articles, yet his drawing shows a ratio of 10:17.5, more like these specimens (in the female they have the ratio of 10:18.5). Finally, in the dactylus of the third leg, de Man shows a uniform tapering curve, but these specimens have a rounded thickening two-thirds of the length distally, similar to that described for *A. gracilis* var. *simplex* (Banner, 1953: fig. 25k).

#### *Alpheus pachychirus* Stimpson

*Alpheus pachychirus* Stimpson, Acad. Nat. Sci. Phila., Proc. 12: 30, 1860.

LOCALITIES: Banner, 1 specimen; Cloud, 1 specimen at E-4, 3 at Loc. 9.

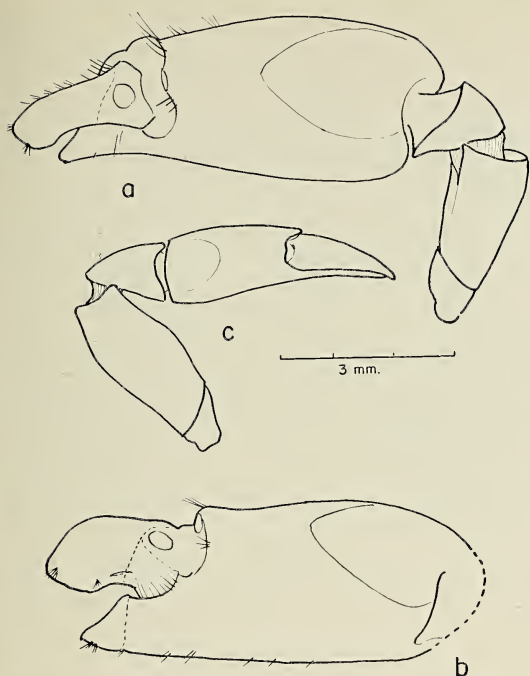


FIG. 18. *Alpheus ovaliceps* Coutière. a, b, Large chela; c, small chela.

### *Alpheus ovaliceps* Coutière

Fig. 18

*Alpheus ovaliceps* Coutière, Fauna and Geog. Mald. and Laccad. 2(4): 888, pl. 77, fig. 27, 1905.

LOCALITY: Banner, 3 specimens, Saipan.

DISCUSSION: This species was described by Coutière on the basis of a single male from Minikoi. It has not been reported since then.

These three specimens, two males and a female, agree almost perfectly with the description and figures of Coutière, even to the two long and broadened bristles on the penultimate article of the third maxilliped. However, they do differ in two characteristics. In the Indian Ocean specimen the large chela had a marked taper towards the dactylar articulation and proximal to this articulation there was a slight transverse groove; in the present specimen, the chela maintains its full diameter throughout, and there is no such groove. The small chela is essentially similar

in the two sets of specimens. (I have drawn the small cheliped of the female particularly to show the form of the merus, similar in both sexes.) Secondly, the outer spine of the uropod was reported by Coutière as being dark brown, whereas in these three specimens it is colorless.

Within this group variations are so common that no great significance is attached to these differences. Possibly if other specimens from the Indian Ocean are compared to these from the Western Pacific the differences would be found to intergrade; if they did not, at most they would justify the erection of a subspecies for the Pacific form.

### *Alpheus frontalis* Milne-Edwards

*Alpheus frontalis* Milne-Edwards, Histoire Naturelle des Crustacés, 2: 356, 1837.

LOCALITY: Banner, 1 specimen, Saipan.

### Diadema subgroup

#### *Alpheus diadema* Dana

*Alpheus diadema* Dana, U. S. Explor. Exped. 13: 555, pl. 35, fig. 7, 1852.

*Alpheus insignis* Heller, K. Akad. Wiss. Wien, Sitzungber. 44: 269, taf. 3, fig. 17-18, 1861.

*Crangon diadema* Banner, Pacific Sci. 7(1): 118, fig. 43, 1953. [Neotype established.]

LOCALITIES: Banner, 15 specimens in 3 collections; Cloud, 18 specimens at locality D-5, 1 at Loc. 8.

#### *Alpheus gracilipes* Stimpson

*Alpheus gracilipes* Stimpson, Acad. Nat. Sci. Phila., Proc. 12: 31, 1860.

*Crangon gracilipes* Banner, Pacific Sci. 7(1): 115, fig. 41, 1953.

LOCALITIES: Banner, 55 specimens from 8 collections; Cloud, 10 specimens at locality D-5, 2 at D-6.

DISCUSSION: The specimens of this species from Hawaii bear balaeniceps-shaped dactyli on the small chelae in both sexes; in these from Saipan, however, only the small chela



of the males is broadened and bears the characteristic fringe of setae. In the females the dactylus is slender, tapering uniformly to the acute tip, and lacking all traces of the fringe. Both sexes lack the slight transverse depression proximal to the dactylus.

It is likely that this is a separate subspecies, distinct from the form in Hawaii. However, the decision will be deferred until specimens are examined from other archipelagoes. When Tahitian specimens (the type locality) are examined it will be possible to decide, if a new name is to be applied, which form is similar to Stimpson's type.

***Alpheus paracrinatus* Meirs var.  
*bengalensis* Coutière**

*Alpheus paracrinatus* var. *bengalensis* Coutière,  
Fauna and Geog. Mald. and Laccad. 2(4):  
901, pl. 82, figs. 37-37a, 1905.

LOCALITIES: Banner, 17 specimens in 7 collections; Cloud, 1 specimen each at localities A-5, D-5, FX.

DISCUSSION: Variation is found in these specimens in the relative lengths of the antennular peduncle, the scaphocerite, and the carpocerite. In most the antennular peduncle does not reach to the tips of the other two, and most often the scaphocerite and the carpocerite are subequal. Only on a few specimens is the carpocerite considerably longer than the scaphocerite, as was commonly found in Hawaii (Banner, 1953: fig. 40a, b). In some specimens, on the other hand, the tips of the three parts reach essentially the same point. Variation is also found, as in Hawaii, in the armature of the merus of the large and small chela. In several specimens the fingers of the large chela are proportionately shorter, not more than about 0.2 the length of the chela; in other specimens the fingers of the small chela are much more hirsute. In all of the specimens the first and second articles of the second leg are subequal, the criterion for the separation of this variety from the parent species.

Brevirostris group

***Alpheus rapax* Fabricius**

*Alpheus rapax* Fabricius, Sup. Ent. Syst., p. 405, 1798 [see de Man, 1909: 147-155 for synonymy].

LOCALITY: Guam, collected by Seale, 1900 (Bernice P. Bishop Mus. No. 161).

DISCUSSION: This sole specimen is definitely *A. rapax* as redescribed by de Man. The Hawaiian specimen of this species showed two differences from de Man's redescription: the merus of the small cheliped was lacking in a distal spine on the inferior internal margin, and the third legs were not densely hirsute. This specimen has a very small tooth on the merus, but, as in the Hawaiian specimen, the third legs bear only scattered setae.

***Alpheus* species 3**  
Fig. 19

LOCALITY: A 12 mm. male from Loc. 2, collected by P. E. Cloud, Jr.

DESCRIPTION: Rostrum acute, reaching about 0.7 length of visible portion of first antennular article, rostral triangle slightly longer than broad. Rostral carina strong, extending posteriorly half length of carapace. Orbital hoods inflated, rounded, similar in development to *A. rapax* Fab.

Second antennular article twice as long as broad, 1.3 times as long as first article, about 2 times as long as third. Stylocerite with acute lateral tooth projecting almost to end of first antennular article. Spine of basicerite of moderate development, relatively shorter than stylocerite. Scaphocerite with tip of lateral spine noticeably longer than antennular peduncle; spine exceeding flattened portion in length. Carpocerite slightly longer than scaphocerite.

Third maxillipeds, if extended straight, reaching beyond antennular peduncle. Last article 3.0 times as long as penultimate and 4.0 times as long as broad.

Merus of large cheliped 2.8 times as long

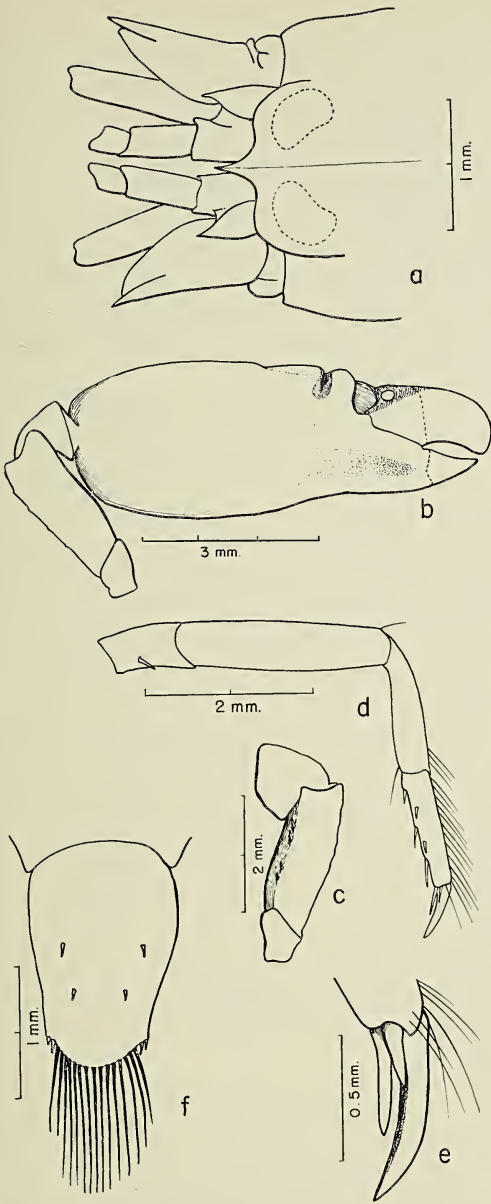


FIG. 19. *Alpheus* species 3. *a*, Anterior region, dorsal aspect; *b*, large chela; *c*, large cheliped, merus; *d*, third leg; *e*, third leg, dactylus; *f*, telson.

as broad, superior margin slightly irregular, inferior internal margin bearing four irregularly placed moveable spines. Chela 2.5 times as long as broad, with palm 1.85 times as long as fingers, with short transverse groove on superior margin, shallow depression on

external face of base of fixed finger; chela with but few scattered setae.

Small cheliped and second legs lacking.

Ischium of third legs 0.3 as long as merus, bearing movable spine. Merus slightly over 4 times as long as broad, unarmed. Carpus half as long as merus, unarmed. Propodus tapering, as long as carpus, bearing five strong spines on or near inferior margin and two distally. Dactylus half as long as propodus, simple, curved, somewhat flattened on inferior margin. Distal end of carpus and entire propodus bearing long fine setae along superior margin.

Telson in specimen asymmetrical, 2.2 times as long as posterior margin is broad, anteriorly 1.4 times as broad as posteriorly; lateral margins anteriorly convex, posteriorly concave, with convexity of right side more pronounced than left; tip broadly arcuate. Dorsal and terminal spines of slight development.

DISCUSSION: It is unfortunate that this specimen is in such poor condition; in addition to lacking the small chela, both second legs, one of the third legs, both fourth legs and one of the fifth legs, the tissue within the exoskeleton is partially shrunk and withdrawn, leaving the exoskeleton without support; the exoskeleton, as a consequence, is difficult to discern and often distorted.

The form of the chela and the anterior carapace plainly places this species within the *Brevirostris* group. The groove of the chela, together with the keel on the carapace, the lack of a tooth on the merus of the third leg, and the narrowness of the same article serves to separate this species from all other species in the group except *A. brevirostris* (Olivier) and *A. savuensis* de Man. It is plainly different from the former in the scaphocerite, for in *A. brevirostris* the flattened portion reaches almost to the tip of the spine (de Man, 1909: fig. 15), and in the large chela, which appears much heavier in the palm and which has a dactylus that is about three times as heavy as the fixed finger (Coutière, 1899: fig. 281).



This form shows a closer relationship to *A. savuensis*, but can be separated from that species by a series of characteristics such as: the rostrum, which is shorter in *A. savuensis*; the rostral carina, which reaches only slightly past the orbital hoods; the stylocerite, which does not bear an acute tip like this form; slight (and possibly not significant) differences in the relative lengths of the antennular peduncle, scaphocerite and carpocerite; similar differences in the dactylus of the third legs, which de Man describes as not flattened, but which are slightly flattened on the inferior face in this specimen. In spite of these differences, which at best are minor, there appears to be much in common in general form between the two, especially in the large chela and third legs.

As the small chela and the second legs are so important in the separation of species in this genus and group, to say that this sole mutilated specimen is or is not the same as *A. savuensis* would be questionable. Likewise, if the specimen were considered as distinct from de Man's, little could be gained by the establishment of this defective specimen as a type for a new species.

#### Edwardsi group

#### *Alpheus ladronis* sp. nov.

Fig. 20

TYPES: Holotype, a 10.8 mm. male, collected by A. H. Banner, Saipan; allotype, a 13.0 mm. ovigerous female; paratype, a partially broken ovigerous female, same length; both females from same collection as male. Types to be deposited in the U. S. National Museum.

DESCRIPTION: Rostrum small, acute, reaching almost to middle of visible portion of first antennular article; lateral margins of base demarked from almost straight orbitorostral margins; sharp rostral carina extending to near posterior margin of eyes, continuing low and rounded, and soon merging with curvature of carapace; in lateral view carina higher

than orbital hoods, depressed anteriorly. Orbital hoods relatively low, rounded, separated from carina by shallow rounded depressions.

Second antennular article 1.7 times as long as broad, 1.1 times as long as first, 1.5 times as long as third. Stylocerite reaching to end of first antennular article. Basicerite armed with small, acute tooth. Lateral spine of scaphocerite reaching to end of third antennular article, squamous portion almost as long. Carpocerite reaching slightly beyond end of scaphocerite.

Large chela compressed, 2.6 times as long as high, with fingers occupying the distal 0.3. Transverse groove proximal to dactylar articulation shallow and rounded, continuous on inner face as shallow rounded depression, U-shaped in outline, and on outer face as deeper, well-delimited groove extending proximally past middle of palm. Shoulder on inferior margin conspicuous, extending up both inner and outer faces. Dactylus and fixed finger with acute tips. Merus 0.3 as long as chela, with outer inferior margin rounded, superior distal margin slightly produced into a low, obtuse tooth, inferior internal margin bearing a strong tooth subterminally.

Carpus of second legs with ratio: 10:7:3:3:6.

Small chela 4.1 times as long as broad, fingers slender, tapering (not belaeiceps-shaped), occupying distal 0.6. Merus slender, unarmed.

Third legs with ischium unarmed; merus 4.6 times as long as broad, carpus 0.5 as long as merus, with superior margin continuing distally as rounded projection; propodus 0.77 as long as merus, armed along inferior margin with six relatively long, slender spines; dactylus simple, curved, slightly less than 0.3 as long as merus.

Telson 2.1 times as long as broad posteriorly, 1.6 times as broad anteriorly as posteriorly; margins rounded, with arcuate posterior margin a continuation of curved lateral margins. Dorsal spinules on type asymmetrical, as shown in Figure 20*i*. Lateral spine

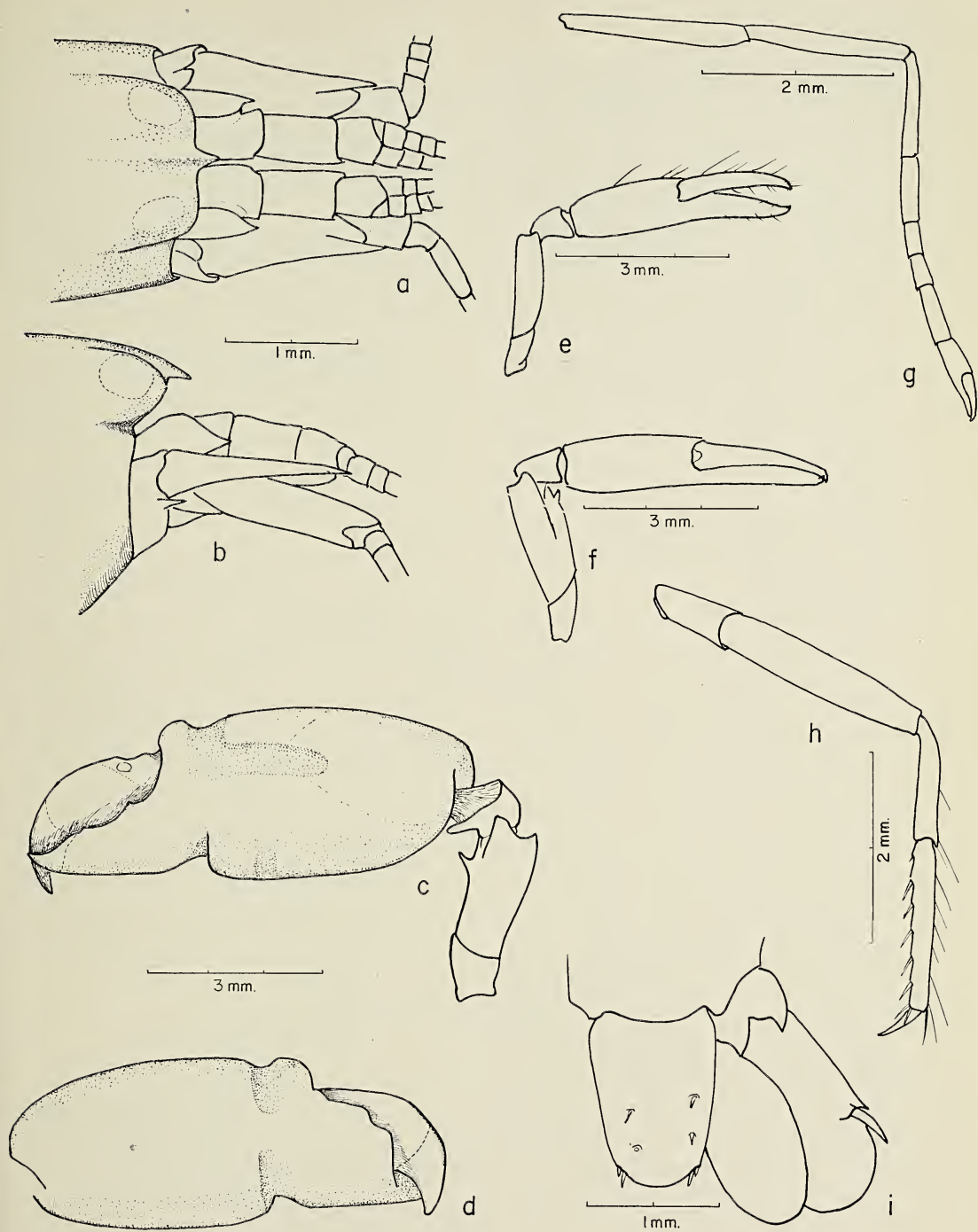


FIG. 20. *Alpheidus ladronis* sp. nov. *a, b*, Anterior region, dorsal and lateral aspects; *c, d*, large chela, lateral and medial aspects; *e*, small cheliped, male (type); *f*, small cheliped, female (allotype—setae not shown); *g*, second leg; *h*, third leg; *i*, uropods and telson.



of outer uropod strong but exceeded by distal curved margin.

DISCUSSION: The two paratypes differ in two important ways from the type: in both the merus of the small chela carries a tooth similar to that of the large cheliped, and in both the margins of the telson are less rounded, with a more pronounced taper in the posterior half (in one the anterior margin is 1.9, in the other 3.0, times the breadth posteriorly). Other lesser differences were noted in the fingers of the large chela, which are more rounded, in slight difference in proportions in the carpus of the second legs, and in the uropods, which do not protrude as far beyond the lateral spine. It is likely that the difference in the fingers of the large chela, and it is possible that difference in the armature of the merus of the small chela, are secondary sexual characteristics; the other differences probably are normal variation.

This species plainly belongs to the Edward-sii group, and within that group appears to be most closely related to *A. bouvieri* A. Milne-Edwards and *A. bastardi* Coutière. From the latter it differs in the form of the rostrum, the more slender form of the small cheliped, and, if a specimen from Yap to be reported in a later publication is the same as Coutière's species, in the presence of the meral spines of the large chela and the absence of ischial spines of the third legs. From *A. bouvieri* it differs most notably in the absence of sexual dimorphism in the small chela; it apparently also differs in the presence of teeth on the basicerite and the merus of the large chela. Unfortunately, complete descriptions are not available for either of the species and it is possible that *ladronis* will be found either to be more closely related or more widely separated when the types are compared.

The specific name is derived from Magellan's name for the Mariana Islands.

### *Alpheus pacificus* Dana

*Alpheus pacificus* Dana, U. S. Explor. Exped. 13: 544, pl. 34, fig. 5, 1852.

*Crangon pacifica* Banner, Pacific Sci. 7(1): 138, fig. 50. [Neotype established.]

LOCALITY: Banner, 2 specimens from one locality, Saipan.

DISCUSSION: Although these specimens are small and immature, they compare well to specimens of similar size from Hawaii. It is notable that in the large collection of specimens from Saipan only two specimens of this species were found, yet it is one of the most common in Hawaii.

### *Alpheus leptochirus* Coutière

*Alpheus leptochirus* Coutière, Fauna and Geog. Mald. and Laccad. 2(4): 914-916, pl. 87, fig. 54, 1905.

SPECIMEN: Banner, a single specimen, Saipan.

DISCUSSION: This sole specimen, a male, is very similar to the female reported from Hawaii (Banner, 1953: 133, fig. 48) in all characteristics, and in those points where the Hawaiian specimen differs from the type, it is more similar to the Hawaiian specimen than to the type, except that in the first two carpal articles of the second leg the ratio is 10:9, intermediate between the ratio of 10:11 in the Hawaiian specimen and 10:7 in the type. Another slight point of difference is in the armature of the merus of the small and large chelae, which, instead of bearing movable spines as did the previous forms, bear short stiff setae.

### *Alpheus dolerus* sp. nov.

Fig. 21

TYPES: Holotype, a 17.0 mm. male collected on Saipan in 1944 by A. H. Banner; allotype, a 14.6 ovigerous female from the same collection; paratypes, 12 specimens in 6 collections by A. H. Banner; 1 specimen from Loc. 6, collected by P. E. Cloud, Jr.

DESCRIPTION: Rostrum acute, reaching to end of first antennular article, continued posteriorly to slightly behind corneas as low

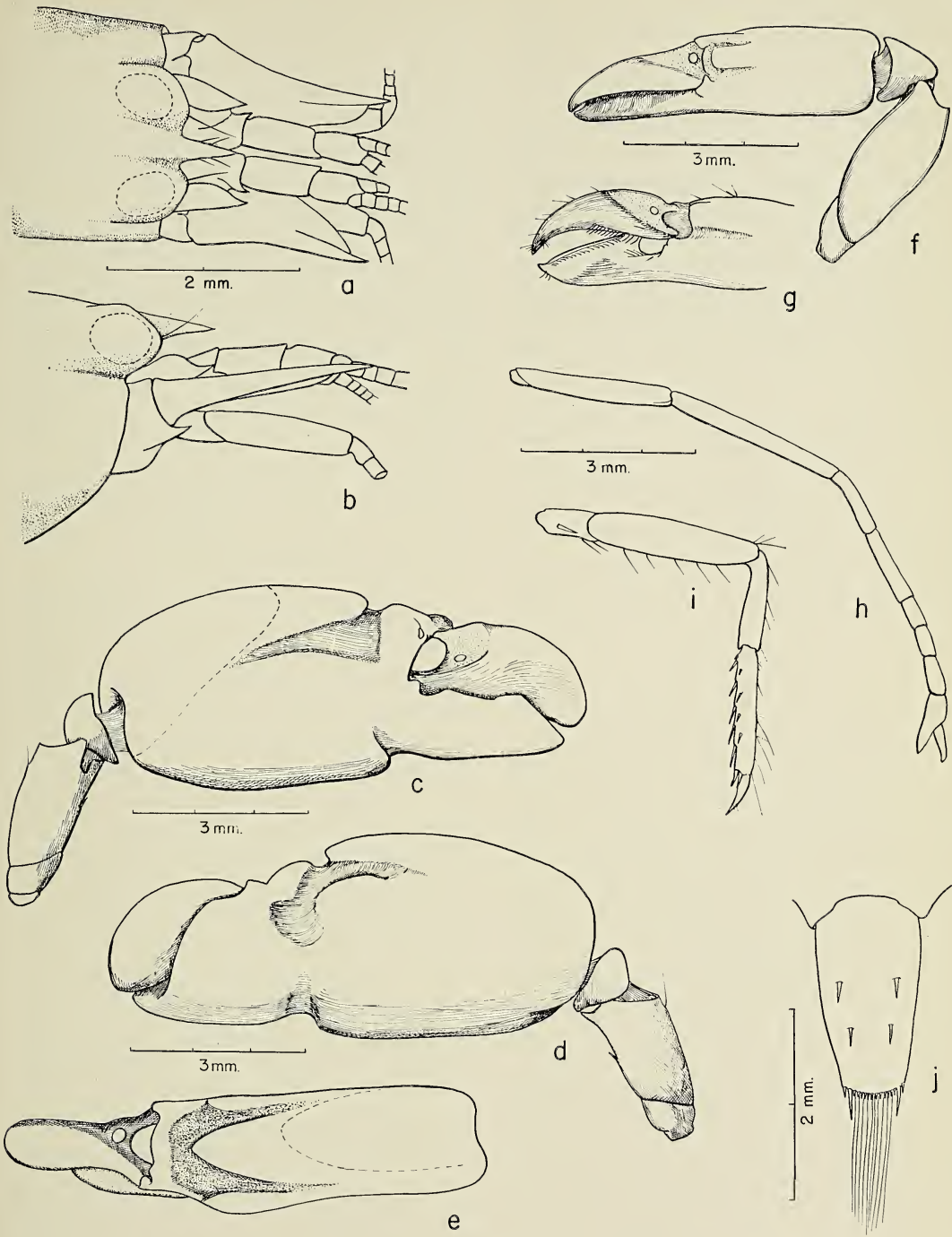


FIG. 21. *Alpheus dolerus* sp. nov. *a, b*, Anterior region, dorsal and lateral aspects; *c, d, e*, large chela, lateral, medial and dorsal aspects; *f, g*, small chela; *h*, second leg; *i*, fourth leg; *j*, telson.



rounded ridge; lateral margins bearing two stiff setae. Orbital hoods rounded, slightly inflated; orbitorostral area depressed, shallow, rounded.

Second antennular article twice as long as broad, slightly longer than first and third articles; lateral spine of stylocerite reaching to end of first antennular article. Lateral spine of basicerite small but acute; tip of spine of scaphocerite reaching beyond end of antennular peduncle; squamous portion of scaphocerite narrow, reaching to end of antennular peduncle; carpoperite slightly shorter than scaphocerite.

Large chela compressed, massive, 2.6 times as long as broad, with fingers occupying distal third. Palm with sculpturing common for group, superior transverse groove continuous with triangular depressed areas on either face; proximal margin of groove, when seen in profile, vertical to margin of palm. Inferior lobe slightly distal to superior groove, strong, and continuing to 0.25 height of palm on outer face; rounded on inner face. Dactylus heavy, compressed, superior margin rounded. Length of merus equal to about 0.5 height of palm, outer face less than 2.5 times as long as broad; inferior internal margin sharp, bearing single movable spine in middle, and distally produced into strong, acute tooth.

Small chela 3.2 times as long as broad, with fingers occupying distal 0.5; palm proximal to adhesive plaque slightly raised, rounded, with shallow depressions on either side; no teeth about digital articulation. Dactylus slender, tapering and curved, with slight trace of setiferous expansion on proximal portion; inner face bearing knife-like ridge that meets corresponding ridge on fixed finger; knife ridges of both fingers paralleled by row of short stiff setae. Merus half as long as chela, slightly over twice as long as broad, bearing movable spine and distal tooth like that of large cheliped on inferior internal margin.

Carpus of second legs with ratio: 10:11:4.2:4.5:5.8.

Ischium of third legs bearing strong mov-

able spine; merus 4.3 times as long as broad, distally unarmed; carpus 0.5 length of merus, superior and inferior margins produced but rounded; propodus 0.7 as long as merus, bearing five strong spines on inferior margin, five smaller spines near margin, two strong spines distally. Dactylus simple, tapering, curved, 0.25 length of merus.

Telson 3.3 times as long as tip is broad, 1.8 times as broad anteriorly as posteriorly; lateral margins slightly concave in posterior third; tip broadly arcuate, larger spines about half as long as tip is broad, tip also bearing series of short spinules above bases of setose bristles; anterior pair of dorsal spines before middle.

Paratype similar to holotype in all characteristics except that length of merus of large chela is approximately equal to height of palm and relatively more slender.

DISCUSSION: The specimens in the paratypic series exhibit the normal and expected variations. In some, especially the smaller specimens, the rostrum is shorter, in one extreme case reaching only to the middle of the visible portion of the first antennular article. On the meri of both chelae the number of spines is variable, from none (especially on the smaller cheliped) to three; in one specimen, of questionable identity because it was small and broken, there are eight movable spines. The large chela itself often is somewhat more slender, in one reaching the maximum of 3.0 times as long as broad. In several specimens the tips of the fingers are calcified and white. The relative lengths of the spines on the propodus of the third legs are also variable, some being shorter and others being longer than those depicted for the type specimen. In the telson of many specimens the margins of the anterior portions are straighter and more parallel, posteriorly the margins are more deeply concave, the tip is relatively narrower.

In one female from the collection that produced the type and allotype the setae, but not the spines, of the telson, uropods and

posterior pleopods were dark, almost black, contrasting with the alcohol-bleached body.

This species plainly belongs to the Edwardsii group of the genus, and can be separated from most other members of the group by the form of the rostrum, the lack of a meral tooth, the simple dactylus of the third legs, and the simple condition of the dactylus of the small chela in both sexes. In the key of de Man (1909: 325) this species comes out to *A. baanii* Ortmann, but the two species cannot be confused because *baanii* bears deep grooves arising both medially and laterally to the orbital hoods that almost encircle the orbital hoods according to de Man's redescription of the type specimen (1897: 751); moreover, the second carpal article is definitely shorter than the first (ratio of 2.3:1.5 instead of 10:11).

This species looks very similar to the specimens which I identify as *A. leptochirus* Coutière. If it were not for the lack of the fringe of setae on the dactylus of the small chela of the male, the two would have been considered to be a single species. In fact, the great similarity renders questionable the use of this fringe of setae as a specific characteristic. However, as there is no evidence, only suspicions, about the validity of this accepted criterion, it was decided to describe this species as new.

The name is derived from the Greek *doleros* —deceptive.

### *Alpheus parvirostris* Dana

*Alpheus parvirostris* Dana, U. S. Explor. Exped. 13: 551, pl. 35, fig. 3, 1852.

LOCALITIES: Banner, 65 specimens in 9 collections; Cloud, 2 specimens at A-5, 1 at C-7a, 6 at D-5, 2 at Loc. 6.

DISCUSSION: These specimens agree very well with the redescription given by de Man (1911: 432) and with the short original description. There are several minor but noteworthy variations, however. De Man stated that the length of the first carpal article of the

second legs was about twice the length of the second article, whereas in most of these specimens it ranges from 1.5 to 1.8 times as long. The tooth on the inferior margin of the third and fourth legs varies in its development, with that of the fourth legs at times lacking, and that of the third legs quite small; this variation appears to be roughly correlated with size, with the smaller specimens showing a poorer development of the meral tooth. Like de Man's specimens, these specimens showed variation in the relative lengths of the stylocerite, scaphocerite and especially the lateral spine of the basicerite.

Coutière's statement of distribution for this species (1905: 906), that it is found "depuis le cap jusqu'aux îles Sandwich. . ." is not based on any other published record, and the species was not found in the extensive Hawaiian collections previously reported upon (Banner, 1953). It is likely the statement is erroneous.

### THUNOR

In 1949 Armstrong (1949: 12) erected a new genus *Thunor* for the species described by Schmitt as *Crangon rathbunae* (1924: 74) from the Barbados. He separated *Thunor* from *Alpheus* (*Crangon*) primarily on the basis of four characteristics: 1, The obsolescence of the ocular beak, the anterior projection arising between the bases of the eye stalks. 2, The absence of the cardiac notch, a notch on the posterior margin of the carapace between the attached dorsal region and the bases of the branchiostegites. 3, The lack of anal tubercles, projections on the ventral side of the telson flanking the anus and engaging the inner uropods. 4, The absence of a transverse articulation on the outer uropod. There were also two other characteristics that Armstrong evidently considered as less important: The rostrum was absent and the outer branch of the palp of the first maxilla lacked setae. Otherwise the genus was like *Alpheus* with the large chela like that of the *Obesomanus* group; moreover, the type species, *T. rath-*



*bunae* has an elongation of the antennular peduncle and the extreme reduction of the parts of the antennal base that is also common in the *Obesomanus* group. Armstrong felt that *T. rathbunae* was most closely related to *A. idiocheles* Coutière (printed *idocheles*, *lapsus calumi*), an unusual species that Coutière placed in the *Megacheles* group with doubts. These two species are closely related; as I am tentatively accepting *Thunor* I am transferring the species *idiocheles* to this genus and adding another species here referred to as *T. species 1*.

To review the validity of this separation I have examined specimens that I consider to be related to *T. rathbunae*, to *T. idiocheles* or to the *Obesomanus* group. These include specimens identified as *T. idiocheles*, *A. lutini* Coutière, *A. microstylus* (Bate), *A. phrygianus* Coutière, *A. perplexus* and *A. chamorro* and three specimens, possibly belonging to new species, too incomplete for specific identification, *A. species 2*, and *T. species 1*. The characteristics of these species are discussed in their individual sections; here only the way they meet the criteria of Armstrong is considered.

1. The ocular beak. As this characteristic is impossible to see unless the specimen is either distorted in capture or the intact specimen torn apart, I do not feel inclined to ruin one of the small number of specimens representing some species. The character was not examined in *A. lutini*, *A. perplexus*, *A. chamorro*, and *A. species 2*, in the others it is as follows:

*T. idiocheles* and *T. species 1*—lacking.

*A. microstylus*—present but poorly developed.

*A. phrygianus*—present, of moderate development.

2. The cardiac notch. In most specimens this characteristic is difficult to discern because the posterior margin of the carapace is not well defined, and, being transparent, tends to be indistinguishable from the opaque white of the underlying tissues.

*T. idiocheles*, *A. lutini*, *microstylus*, and *chamorro*—cardiac notch present.

*A. phrygianus*—cardiac notch lacking, but dorsal region set off from brachiolegites by an angle.

*A. species 2*—region rounded where cardiac notch should occur.

*T. species 1*—slightly developed cardiac notch in male, margin without notch but angular, not rounded, in female.

3. The anal tubercles. In those species in which they are present, they are well developed in the form of a small papillose structure; otherwise there is no vestige of them.

*T. idiocheles*, *T. species 1*—lacking anal tubercles.

*A. lutini*, *microstylus*, *phrygianus*, *perplexus*, *chamorro*, and *A. species 2*—anal tubercles present.

4. Articulation of the outer uropod. Often this is difficult to see in preserved specimens. It can best be checked by bending the tip of the uropod ventrally and noting whether it bows in a rounded fashion or bends sharply along the line of articulation.

*T. idiocheles*, *T. species 1*—without articulation.

*A. lutini*, *microstylus*, *phrygianus*, *perplexus*, *chamorro*, and *A. species 2*—with articulation.

In this series of species, e.g., *A. species 2* and *T. species 1*, as well as those previously reported, e.g., *A. microstylus*, the presence or absence of the rostrum is variable within the species. In no specimens were the maxillae examined.

To recapitulate Armstrong's criteria: the ocular beak as the basis for working separation appears to be valid but impractical, especially where only a few specimens are available; the cardiac notch appears to be too variable; leaving for the separation of the two genera only the two characteristics, the anal tubercles and articulation of the uropods. If this separation is made, then *T. idiocheles*, and *T. species 1* belong to *Thunor*.

Opposed to this separation would be a series of characteristics, for the species agree well with *Alpheus* for the most part. The ex-

treme form of the rostral front of *T. rathbunae* is approached in a number of species plainly belonging to *Alpheus* (including *A. species* 2); the peculiar development of the antennules and antennae is approached by many species of the *Obesomanus* group; the large and small chelae are similar to those found in the *Obesomanus* group; there is nothing in the second and subsequent thoracic legs and pleopods that would serve to separate the two genera; even the brachial formula is the same.

I, therefore, am in doubt as to the validity of this separation, and believe that at most the species of *Thunor* should be put into a group or subgroup within the genus *Alpheus*. However, until more closely related species are examined in reference to these differences and similarities in order to better determine the constancy of the differences, I will recognize the genus *Thunor*.

### *Thunor idiocheles* (Coutière)

Fig. 22

*Alpheus idiocheles* Coutière, Fauna and Geog. Mald. and Laccad. 2(4): 883, pl. 75, fig. 21, 1905.

LOCALITIES: Banner, 5 specimens in 4 collections; Cloud, 1 specimen at locality D-7.

DISCUSSION: These specimens agree very well in almost all characteristics with those in Coutière's description. However, there are some variations that should be noted. The rostrum is found to vary slightly in proportions, from a slight triangle to one that reaches as far anteriorly as the rounded anterior end of the stylocerite. In all specimens the rostral carina is marked. The carpopocerite and lateral spine of the scaphocerite in one specimen are equal in length to each other and reach only to the end of the second third of the second article of the antennular peduncle, in other specimens they are unequal with the carpopocerite only reaching to the end of the second antennular article, and in one specimen the spine of the scaphocerite reaches to the end of the second antennular article and the

carpopocerite exceeds it, reaching almost a third the length of the third antennular article. Of the four specimens which retain a large chela, three have a length-breadth ratio of 3, instead of 3.5 as reported by Coutière. The telsons are quite variable, and in none were the posterolateral spines poorly developed as those shown by Coutière. Finally, four of the six specimens have a strong brown spine on the external margin of the outer uropod; the other two have more slight and colorless spines; in none are there two short brown spines as described by Coutière.

Two of the specimens have such markedly dissimilar telsons that they were originally thought to be of a different species. These are the specimens illustrated in the figures. Unfortunately neither specimen has its large chela intact. However, as they agree very well otherwise with intact specimens identified as this species, and as the telsons of the four intact specimens are also variable, it is thought that this difference probably is not of significance. Similar wide variation has been reported by Armstrong in *Thunor rathbunae* (Schmitt).

Coutière did not remark upon the lack of an articulation in the outer uropod, and, to the contrary, he showed a line that could be interpreted as an articulation in his figures. None of the Saipan specimens has an articulation although some show a slight line starting transversely from the region of the lateral spine, similar to that shown by Coutière. This faint line, possibly a rudimentary articulation, does not reach to the opposite margin in any specimen.

The cardiac notch of the carapace is present and the anal tubercles are lacking in all specimens.

### *Thunor species* 1

Fig. 23

SPECIMENS: An 8.5 mm. male (carapace length 3.7 mm.) lacking large and small chelae, and one of each pair of posterior



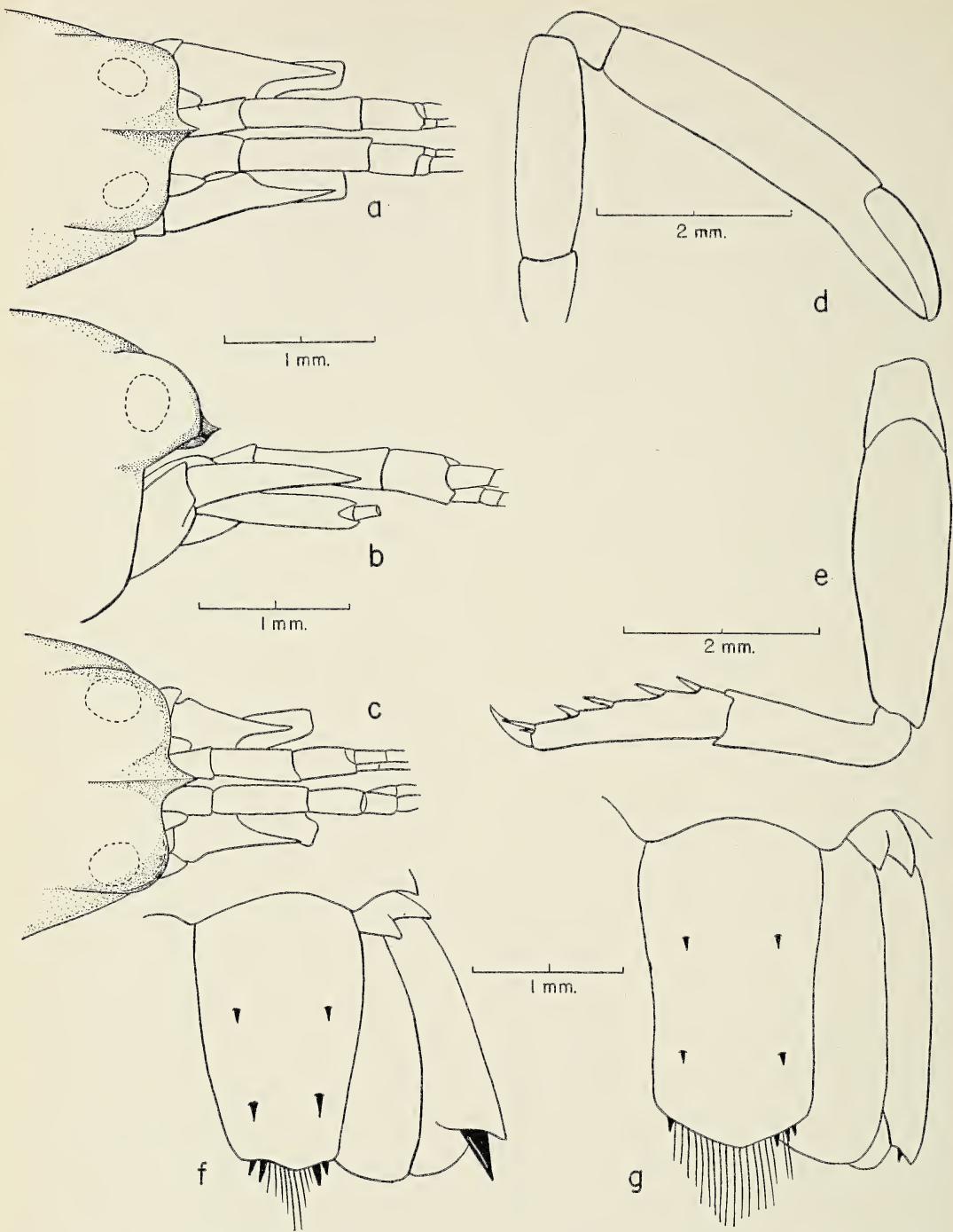


FIG. 22. *Thunor idiocheles* (Coutière), aberrant specimens. *a, b.* Anterior region, dorsal and lateral aspects, male; *c*, same, female; *d*, small cheliped, female; *e*, third leg, male; *f*, telson and uropod, male; *g*, telson and uropod, female.

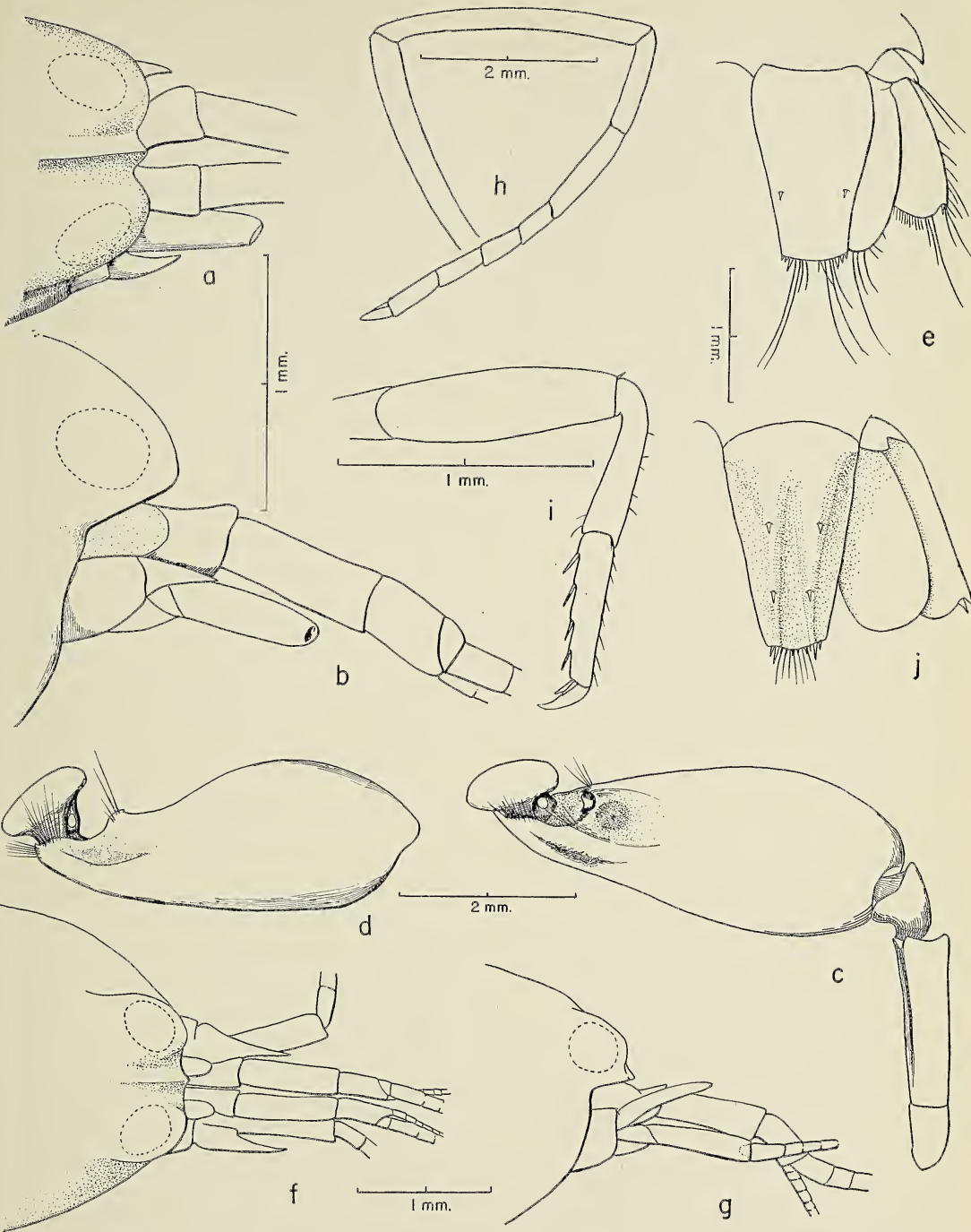


FIG. 23. *Thunor* species 1. a-e, Female: a, b, anterior region, dorsal and lateral aspects; c, d, large cheliped; e, telson and uropod. f-j, Male: f, g, anterior region, dorsal and lateral aspects; h, second leg; i, third leg; j, telson and uropod.



thoracic legs; a 10.4 ovigerous female (carapace length 3.9 mm.) lacking all thoracic legs except the large chela, basal articles of 2nd and 4th legs, and 5th legs. Specimens collected at the same time by A. H. Banner.

**DESCRIPTION:** Body heavy, with cephalothorax markedly heavier than abdomen; thoracic legs long and heavy. (Because of the differences between the male and the female the descriptions will be given separately.)

*Male.* Anterior carapace rounded and depressed in lateral view. Orbital hoods inflated, rounded anteriorly, and higher in lateral view than interorbital area. Rostrum small, triangular, acute, and bearing a low but sharp carina that extends posteriorly to behind orbital hoods. Margin of carapace between anterior orbital hoods and rostrum almost straight.

Antennular peduncle long and slender, with second article 4 times as long as broad and about twice as long as visible portion of first and third articles (third article slightly longer than first). Stylocerite rounded, reaching only 0.5 length of visible portion of first article. Outer flagellum 1.1 times as long as peduncle, inner flagellum slightly longer than outer.

Basicerite unarmed. Scaphocerite reduced, with tip of lateral spine reaching only to middle of second antennular article; blade almost rudimentary, reaching only to end of first antennular article. Carpocerite reaching end of second antennular article. Flagellum long, about 2.5 times as long as outer antennular flagellum.

Carpal articles of second legs with the ratio: 10:12:4.5:5.2:6.0. Chela as long as basal carpal article, with fingers occupying only distal 0.3.

Third legs with ischium unarmed. Merus unarmed, 3.5 times as long as broad. Carpus with superior distal margin projecting as a heavy rounded tooth, inferior margin unarmed; 0.57 as long as merus. Propodus 0.64 length of merus, 4 times as long as broad proximally, and tapering distally; armed with four strong spines on inferior margin and two

distally. Dactylus simple, curved, slightly less than 0.3 the length of propodus.

Pleura of anterior abdominal somites rounded. Uropods of usual form and armature except strong spine of outer uropod brown and outer uropod without trace of distal articulation. Telson 4.0 times as long as posterior margin is broad, 2.5 times as broad anteriorly as posteriorly; lateral margins almost straight, posterior lateral corners rounded, posterior margin slightly arcuate. Anterior pair of spinules 0.4, posterior pair 0.7 of length of telson posterior of articulation; posterior lateral pairs of spinules of moderate development; central tuft of setae of usual form but short, and telson bearing at bases of setae a series of short spinules. Dorsal surface of telson without usual uniform convexity, but bearing two low rounded ridges that merge anteriorly.

*Female.* Orbital hoods similar in form to those of male. Rostrum slightly asymmetrical, rounded; dorsal carina higher and more rounded than in male. Margin of carapace between orbital hoods and rostrum not straight but with rounded and asymmetrical indentations.

Antennular peduncle similar to that of male except stylocerite concealed by carapace in dorsal view. Flagellar lengths about same as in male.

Basicerite unarmed, rounded. Scaphocerite extremely reduced, a simple, heavy, acute triangle, with tip reaching almost to end of first antennular article. Carpocerite reaching only slightly past middle of second antennular article. Flagella broken.

Large chela slightly compressed at base, with rounded margins; 2.7 times as long as greatest width, strongly tapering towards fingers. Dactylus hammer-shaped, with length of "head" about 0.2 length of entire chela. Fixed finger rounded, hardly extending beyond articulation of dactylus, much shorter than dactylus and not meeting in apposition. Palm of large chela with two rounded ridges distally leading towards palmar adhesive plaque; adhesive plaque borne on eminence

that is proximally delimited by deep, rounded concavity that accommodates end of "head" of dactylus when dactylus is flexed. Palm also bearing shallow, triangular depression or groove near dactylar articulation; corresponding area on inner face marked by much less extensive depression. Merus of cheliped 4 times as long as outer face is broad, unarmed.

Outer uropod short, abruptly truncate; spine at termination of outer shoulder poorly developed; ramus with small distal triangle that appears to have resulted from a fracture, not an articulation; tip bearing only few long setae. Inner uropod of usual form but with only occasional long setae. Telson 2.9 times as long as tip is broad, 1.8 times as broad anteriorly as posteriorly; lateral margins anteriorly convex, posteriorly slightly concave, slightly asymmetrical; posterior lateral corners rounded; tip very slightly arcuate; superior surface smooth, armed with but a single pair of spines of feeble development located 0.7 of the length posterior to articulation; on tip three pairs of spines and two pair only of long setae adjacent to spines, three shorter setae on left, two on right, middle of tip devoid of all setae.

Eggs without developing larvae, subspherical, 0.6 mm. diameter.

DISCUSSION: These two fragmentary specimens are perplexing. The question arises as to whether they are of the same species. The general form of the anterior carapace, the antennules, the few appendages that they have in common, are similar, yet there are marked differences in the rostrum, in the scaphocerite and especially in the telson and uropods. Unfortunately, because of the fragmentary condition of the specimens, comparison cannot be made in the thoracic legs. In view of the considerable variation that has been noted in the species of *Thunor* and in related Obesomanus group of the genus *Alpheus*, in view of the general similarities noted, and especially in view of the fact that this pair, male and female, were collected together and may have been therefore a cohabiting pair, I be-

lieve that they represent a single species and their differences are individual variations.

The lack of anal tubercles and the lack of the articulation on the outer uropod place this species in the genus *Thunor*. These two fragmentary specimens can be distinguished from *T. idiocheles* (Coutière) in the proportions of the antennular peduncle, the greater reduction of the scaphocerite and, most important, in the depression on the palm of the large chela behind the dactylar articulation and the pronounced hammer-shape of the dactylus of this appendage. This species can be distinguished from the Caribbean *T. rathbunae* by the presence of a rostrum. Another specimen of this species, more complete, is available in another collection, and with that as the type the species will be described and named in a later paper.

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- . date of publication of Dana's volume on the Crustacea. L. B. Holthius has pointed out to me in a personal communication that this is only the date that the U. S. Printing Office delivered 58 official copies of the work to the Department of State, and that the unofficial copies must have been distributed earlier, for the *American Journal of Science* (Ser. 2, 15: 466, 1853) acknowledges the receipt of this volume in December, 1852. Therefore the generally accepted date of publication, 1852, is the correct one.
- Dr. Holthius also pointed out that the part of volume 6 of the proceedings of the Academy of Natural Sciences, Philadelphia, that carries Dana's "Conspectus Crustaceorum etc.," and which bears the volume date of 1854, must have been published by May, 1852 (*op. cit.* 6(3): 71, 72), so for questions of priority for Dana's species, this earlier date should be used.
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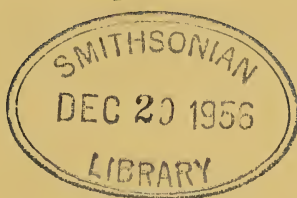
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A QUARTERLY DEVOTED TO THE BIOLOGICAL  
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## Diatoms in the Ocean Depths

E. J. FERGUSON WOOD<sup>1</sup>

THE CONCEPTION of a rain of diatoms from the plankton to the ocean depths is, at first thought, a reasonable one. Further thought, however, makes it appear extremely unlikely. Because diatoms occur in swarms, particularly in certain areas of the oceans, it seems to have been assumed that they descend more or less vertically to form diatomaceous ooze. In fact, in deeper waters, we could expect them to become widely dispersed, especially as their form is such as to retard vertical movement. Further, there is the question of the gradient of silica concentration with depth, and the effect of pressure thereon. Harvey (1945) states that the silica content of seawater, in general, has been found to increase with depth, and that it is probably in true rather than colloidal solution. This suggests that the diatom tests are dissolved as they fall through the water after the death of the cell.

Wiseman and Hendey (1953) found large numbers of the diatom *Ethmodiscus rex* (Rattray) Hendey in material collected from the Mariana Trench by H.M.S. "Challenger" in 1951. These authors speculate regarding the origin of the tests, pointing out that *E. rex* is rare in the plankton, and that, "there is no indication that the species is found living in the waters immediately over the deposit itself." They do not consider the possibility that the diatom is autochthonous.

During a microscopic examination of a mud sample from the Weber Deep (depth, 7,400 m.) in a search for living bacteria, I observed a number of benthic types of diatom frustules. The sample studied was collected by Claude E. ZoBell and Richard Y. Morita during the "Galathea" expedition in 1951, and has since been kept in a pressure bomb at 10,500 p.s.i. and 10°C.

### MICROSCOPIC OBSERVATIONS

Some of the frustules seen appeared to contain protoplasmic material (Fig. 1), as did some *Globigerina* and *Nummulites* which were also observed. Some showed dense spherical bodies, usually four in number, which could have been microspores (Figs. 2, 3). The larger *Coscinodiscus* forms appear to have burst, as did the form shown in Figure 3, probably owing to the rapid release of pressure when the bomb was opened. The smaller *Coscinodiscus* remained intact for the most part.

The cells from some preserved material were stained with various aniline dyes and took up the stain. When stained with acridine orange and viewed under fluorescent light they fluoresced orange-red, whereas the empty frustules did not fluoresce. Hence it may be concluded that the stained cells did contain protoplasm. It is impossible that both cell and protoplasm could have been preserved intact during a slow descent of 7,400 metres from the photic zone, so the evidence that these forms are autochthonous is very strong. Further, many of the frustules of all the species

<sup>1</sup> Scripps Institution of Oceanography, La Jolla, California, U.S.A. and Marine Biological Laboratory, Cronulla, Australia. Manuscript received October 21, 1955.



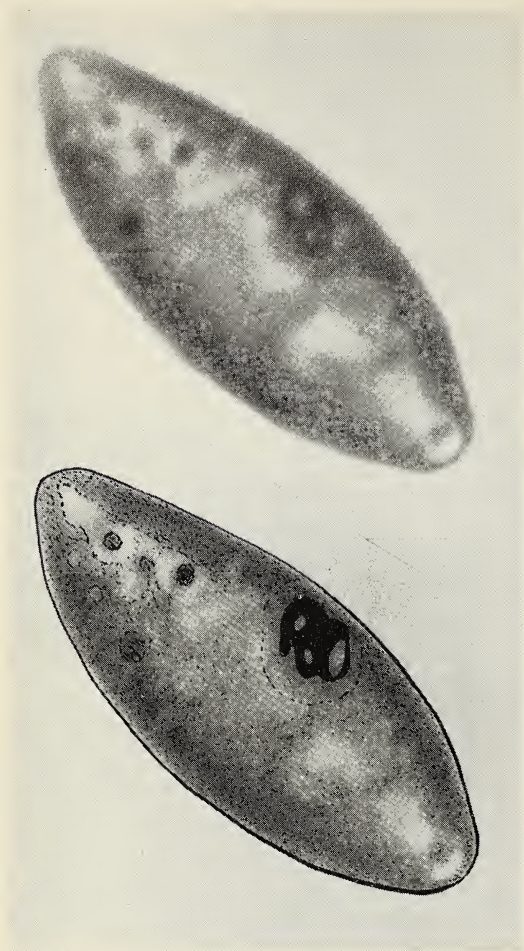


FIG. 1. A naviculoid diatom from the Weber Deep. It contained a brown pigment, vacuoles, fat(?) globules, and nucleus but no chloroplasts. Lower figure retouched. (Phase contrast.)

observed were intact, and appeared quite fresh and uneroded. No planktonic forms were observed, nor were there even fragments of such species as *Rhizosolenia*, *Chaetoceras*, etc., as one would expect from the "rain" theory.

Table 1 lists all of the "Galathea" stations from which bottom material was examined. The samples were first examined directly and again after digestion with hydrochloric acid. Cell contents were seen in material from stations 463 and 492.

In Table 2 the species of diatoms observed and the station from which they came are listed.

The samples all contained numerous sponge spicules, and the presence of these and of the sessile forms *Synedra* and *Melosira* suggest that these diatoms may be epiphytic on the sponges. It is interesting to note also that all, or nearly all, the forms mentioned in Table 2 are found as fossils, and that *Melosira granulata* and *Cocconeis pendiculus* are not recorded from seawater. Since the flora associated with the ocean deeps is unique, it would appear that we are dealing with a separate biocoenosis. Studies made by ZoBell (1952) on the bacterial flora contained in the same samples confirm this.

#### EXPERIMENTAL

If the diatoms are autochthonous, as I suggest, they must be living saprophytically. Recently, Lewin (1953) has described experiments in which diatoms were grown heterotrophically in the dark in a medium containing tryptone and glucose. She points out in her paper that if the diatom cultures are not pure, the bacteria outgrow the diatoms. Accordingly I obtained two cultures of her heterotrophic strains in order to test their growth under pressure, at the same time endeavouring to grow some diatoms in culture from the "Galathea" material.

All the cultures were made in the following medium—an adaptation of that suggested by Lewin:

Solution a	$K_2HPO_4$	0.02 g.
	$MgSO_4, 7H_2O$	0.02 g.
	$CaNO_3, 4H_2O$	0.01 g.
	Glucose	5 g.
	Tryptone	1 g.
	Distilled water	100 ml.
Solution b	Seawater	900 ml.
	Agar (if required)	15 g.

The solutions were sterilized separately and after cooling to about 50°C. were combined.

The cultures, placed in small tubes so as to leave an airspace above, were closed with neoprene stoppers, placed in pressure bombs (ZoBell and Oppenheimer, 1950) and pressurized at 1, 100, 200, and 500 atmospheres.



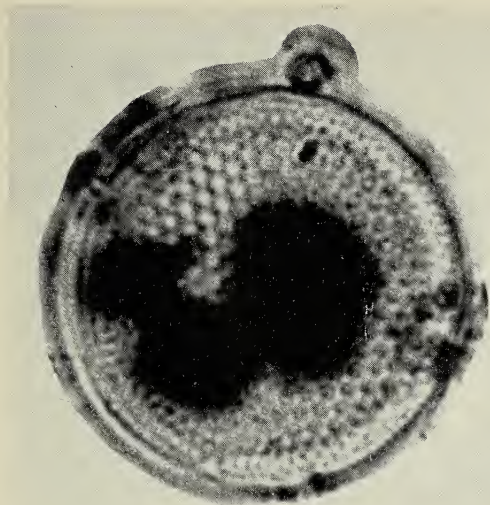


FIG. 2. *Coscinodiscus marginatus* Ehr. from Weber Deep showing dense spherical bodies (microspores?).

In addition, the "Galathea" material was pressurized at 1,000 atmospheres. In the case of the pure cultures, suspensions were made in a small amount of the medium, and 0.1 ml. was pipetted into the small tubes which were then partially filled with the medium. After 14 days, the bombs were opened, the tubes centrifuged for 15 minutes at 4,000 r.p.m., the density of the deposit estimated, and the material examined microscopically. The following observations were made.

*1,000 Atmospheres Pressure*

"Galathea" material only. Some *Coscinodiscus marginatus* with cell material.

*500 Atmospheres Pressure*

"Galathea" mud. *Coscinodiscus* containing refractile bodies and a long straight rod-like body.

Culture 6 M. Cells square with 2 to 4 green, somewhat refractile bodies, deposit density rated as 1. (Fig. 4a.)

Culture 13 M. Cells oval to rounded, with refractile bodies; greenish to brownish. Deposit density, 1.

*200 Atmospheres Pressure*

"Galathea" mud. *Coscinodiscus* with refractile bodies, and cell material between the valves.

Culture 6 M. Cells square to oblong, with greenish-brown chloroplasts. Notably heavy sediment of cells; density, 2.

Culture 13 M. Cells oval, more elongate than at 500 atmospheres. Chloroplasts brown, nucleus evident; vacuoles frequent, with particles either in Brownian movement or rotating. Cells frequently paired as though they had divided recently.

*100 Atmospheres Pressure*

"Galathea" mud. *Coscinodiscus* observed apparently containing cellular material; other empty tests seen.

Culture 6 M. Cells normal in appearance, i.e., like original culture. Growth heavier than at 1 atmosphere. Density, 2.

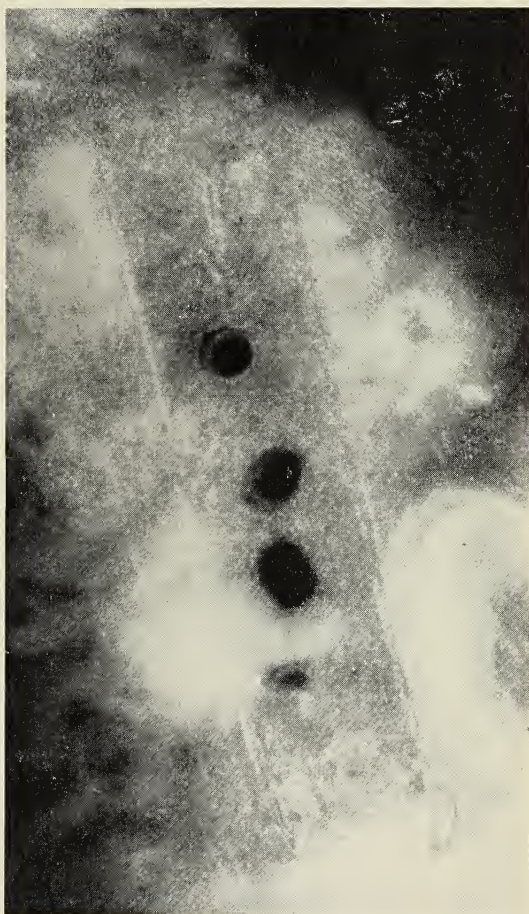


FIG. 3. Naviculoid diatom from Weber Deep which appears to have burst at side and end. (Phase contrast.)



Culture 13 M. Paired cells frequent. Cells oval, frequently with a vacuole at one end containing particles in motion. Fair growth, more than at 1 atmosphere. Density, 1-2.

1 Atmosphere Pressure

Culture 6 M. Cells similar in form to those of parent culture; poor growth. Density, 1. (Fig. 4*b*.)

Culture 13 M. Cells more oval than at high pressure. Density slightly less than at 100 atmospheres.

There appears to have been more growth at 100 and possibly at 200 atmospheres than at 1 atmosphere, but little or no growth at 500 atmospheres. Cells were more square in 6 M and circular (13 M) at high pressures.

Material from these cultures was transferred to agar slopes. Cultures 6 M grew on this medium from 1, 100, 200, and 500 atmospheres, and there was some evidence of growth of 13 M at 500 atmospheres, but the other cultures were overgrown by bacteria.

The experimental evidence suggests that diatoms taken from atmospheric pressure may grow heterotrophically or remain viable at pressures up to 500 atmospheres, and this supports the possibility of the growth of

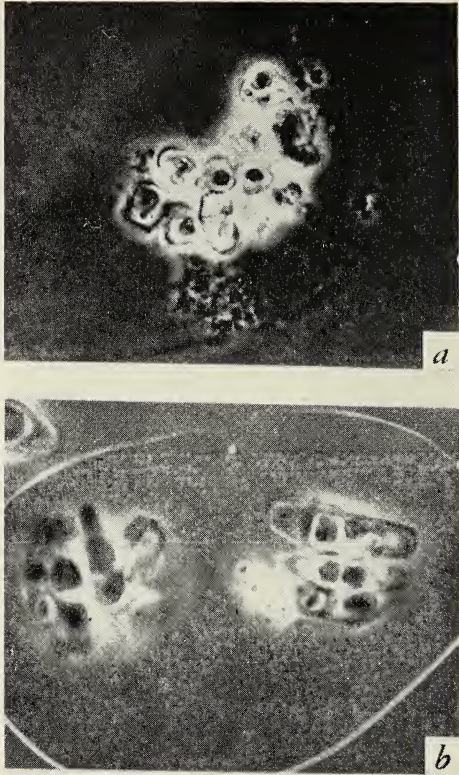


FIG. 4. Diatoms of culture 6M: *a*, Grown at 500 atmospheres pressure; *b*, grown at atmospheric pressure in bomb. (Phase contrast.)

TABLE 1  
SPECIMENS OF BOTTOM MATERIAL EXAMINED COLLECTED BY THE "GALATHEA"

STATION	LOCATION		WATER DEPTH (Metres)	DATE COLLECTED	DEEP	DIATOMS PRESENT
	Lat.	Long.				
418.....	10°20'N	126°30'E	10,387	15/ 7/51	Mindanao	....
422.....	10°49'N	126°01'E	2,010	24/ 7/51	Mindanao	+
440.....	10°25'N	126°40'E	10,610	14/ 8/51	Mindanao	+
463.....	10°16'N	109°51'E	7,214	3/ 9/51	Sunda	+
492.....	5°31'S	131°01'E	7,445	20/ 9/51	Weber	+
496.....	5°36'S	131°06'E	7,465	23/ 9/51	Weber	+
497.....	.....	.....	9,000+	24/ 9/51	Weber	+
517.....	6°31'S	153°58'E	9,020	11/10/51	Solomons	+
517 ?.....	6°31'S	153°58'E	9,255	13/10/51	Solomons	....
608.....	44°31'S	167°50'E	390	18/ 1/52	Milford Sound	+
645.....	35°16'S	178°40'E	8,515-8,425	13/ 2/52	Kermadec	....
650.....	32°20'S	176°54'W	6,794	16/ 2/52	Kermadec	....
658.....	35°51'S	178°31'W	7,837-7,901	21/ 2/52	Kermadec	+
677.....	38°38'S	175°53'W	6,370	4/ 3/52	Kermadec-Tonga	....
678.....	28°30'S	175°53'W	9,437	4-5/ 3/52	Kermadec-Tonga	....
678 (water).....	28°30'S	175°53'W	9,335	4-5/ 3/52	Kermadec-Tonga	....
686.....	20°53'S	175°31'W	10,080	11/ 3/52	Kermadec-Tonga	....

TABLE 2  
DIATOMS OBSERVED IN MUD COLLECTED BY THE "GALATHEA" AND STATIONS AT WHICH THEY WERE TAKEN

SPECIES	STATION NUMBER
<i>Coscinodiscus marginatus</i> Ehr. . . . .	422, 463, 492, 496, 497, 517, 517?, 608
<i>Coscinodiscus pacificus</i> (Grun) Rattray . . . . .	440
<i>Synedra tenera</i> W. Sm. . . . .	463
<i>Melosira granulata</i> (Ehr.) Ralfs. . . . .	463
<i>M. moniliformis</i> Mueller. . . . .	497
<i>Navicula</i> . . . . .	
<i>Nitzschia panduriformis</i> Greg. . . . .	463
<i>Cocconeis pendiculus</i> Ehr. . . . .	463
<i>Diploneis crabro</i> Ehr. . . . .	463
<i>Pinnularia dactylis</i> Ehr. . . . .	440
<i>Ethmodiscus rex</i> (fragts) . . . . .	440
<i>Coscinodiscus centralis</i> Ehr. . . . .	497
<i>Trachyneis aspera</i> (Ehr.) Cleve. . . . .	463
<i>Pleurosigma normani</i> Ralfs. . . . .	497

abyssal diatoms at this and higher pressures. There is a great deal to support the theory enunciated in this paper that the diatoms found in abyssal mud samples may be autochthonous, and, so far, no indication that the flora found in the ocean deeps is allochthonous. Even in shallow estuarine muds planktonic forms are rare or absent except for the heavily silicified *Coscinodiscus*, *Biddulphia*, etc.

ACKNOWLEDGMENTS

I wish to thank Dr. Claude E. ZoBell, and the Rockefeller Foundation, for providing the opportunity for me to visit the Scripps Institution of Oceanography and undertake this work, Dr. Joyce Lewin for cultures of her strains of heterotrophic diatoms, Dr. Carl H. Oppenheimer for taking the photomicrographs, and Mr. L. H. Crosby of the Marine Biological Laboratory, Cronulla, for the specific determination of the diatoms.

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# Beachrock in the Hawaiian Islands<sup>1</sup>

K. O. EMERY and DOAK C. COX<sup>2</sup>

BEACHROCK is a stratified calcareous sandstone (calcareenite) or conglomerate (calcirudite) occurring along many beaches that are composed of shells or other calcareous debris. It is common on beaches of islands that are bordered by coral reefs. Although many authors have described beachrock, few have agreed on its origin, either because critical data are lacking or because beachrock may form in several different ways. Preliminary studies of beachrock in the Marshall, Mariana, and Hawaiian Islands led the authors to believe that detailed mapping of beachrock in the Hawaiian Islands might show whether the distribution is related to abundance and composition of ground water or to other factors of the shore environment.

Examination of the shores of Oahu, Kauai, Molokai, and Maui during parts of June and July, 1954, was made possible by funds from Office of Naval Research contract NR 081-217.

Aid in field mapping, discussion, and critical reading of the manuscript was kindly given by Dr. Douglas Inman of Scripps Institution of Oceanography. Dr. Harold S. Palmer of Honolulu also read the manuscript and made some valuable suggestions.

## GENERAL DESCRIPTION

### *Composition*

The material that becomes cemented into beachrock is beach sand or gravel, chiefly

calcareous. The sand ranges from fine to very coarse and, like other beach sands, is very well sorted (Table 1). Its generally coarse grain size, excellent sorting, and high degree of rounding, make it very permeable. Tests on progressively coarser Oahu samples 14, 2, and 4 of Table 1, yielded permeabilities of 37, 120, and 570 darcys, respectively, values that are comparable with those of other beach sands.

The grains of sand consist chiefly of broken and worn pieces of calcareous parts of organisms, plus minor amounts of volcanic detritus. Volcanic detritus is unusually abundant in beachrock at Ohikilolo (about 2 miles south of Makua) on Oahu where it forms thin brown laminae, and at Kekaha on Kauai where it makes up the bulk of the beachrock as it does also of the unconsolidated sand. Generally, however, the volcanic detritus comprises only a small percentage of the total grains. A summary of the composition of 33 samples of loose beach sand is given in Table 1. The source organisms were identified by shape and mineralogy of the grains: Foraminifera and calcareous red algae being calcite; *Halimeda* and madreporarian coral being aragonite. The mineral form was determined by use of a solution of cobalt nitrate (Meigen's solution) which stains aragonite violet and does not affect calcite. Some pelecypod and gastropod shells consist of both aragonite and calcite; thus some become stained and others are not affected. Accordingly, shells were identified only by remnants of flat or curved surfaces and occasionally by traces of decorative colors. These methods are more fully described in a report on sediments of Guam (Emery, in manuscript). Comparison of the composition of beach sands of the Hawaiian

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Islands, Guam, and Bikini (Emery, Tracey, and Ladd, 1954: 38) shows the same major constituents in all the sands, but some differences in their relative proportions (Table 1). In the Hawaiian beach sands the most abundant constituent appears to be fragments of pelecypod and gastropod shells. Pieces of calcitic debris believed to be from calcareous red algae are next, followed closely by tests of Foraminifera, mainly *Amphistegina* with occasional *Marginopora*. Coral is relatively rare, and *Halimeda* debris was not found. The remaining material, called "fine debris" was too minute to permit visual identification of source organisms. Examination of polished sections of beachrock after similar staining showed the same assemblage of organisms, but percentage determinations were hampered by the presence of much calcitic cementing material.

Gravels that become cemented into beach conglomerate consist of wave-worn coral heads, large mollusk shells, pieces of basalt (Fig. 1), and reworked slabs of older beachrock (Fig. 2). Among the few places where beachrock contains volcanic gravels are areas near Kaena Point, Hauula, and Kapoho Point on Oahu, and Laau Point on Molokai. Silt and clay may also be present in beachrock



FIG. 1. Beachrock  $3\frac{1}{2}$  miles east of Kaena Point, Oahu. Lower layers contain many cobbles of volcanic rock.



FIG. 2. Beachrock at Keaau, Oahu, containing reworked slabs of older beachrock.

but are most conspicuous as distinct interbedded layers of alluvium or soil as at Keaau on Oahu (Fig. 3).

Near Laniloa Point and Kapoho Point on Oahu, and Nohili on Kauai, eolianite overlies beachrock near the high tide level. It may be distinguished by its finer grain size, steeper dip, and generally poorer cementation.

#### Cementation

The cementing material that binds sand into beachrock has been described by Ginsburg (1953), Emery, Tracey, and Ladd (1954: 43–45, 148, 149, pls. 22, 50, 52, 58), Illing (1954: 48, 70), and Ranson (1955) as consisting of calcite with some aragonite. Cementing material in beachrock from the Hawaiian Islands is similar to that described elsewhere, except that no aragonite was found. Failure of any of the pore fillings to become stained with Meigen solution indicates that all of it is calcite. Dr. Heinz Lowenstam of California Institute of Technology kindly confirmed the determination using a different stain.

Thin sections of beachrock from the site of Figure 4 show that pores of the upper layers are more completely filled than those of the lower layers (Table 2). Rinds, 30 to 60  $\mu$  thick and consisting of clear acicular calcite crystals about 4  $\mu$  thick, surround all the grains in the



loose slab, surround less than 1 per cent of the grains in Layer G, and are absent in lower layers. The rest of the pore filling is brown calcite having randomly oriented grains that are more or less equidimensional and about  $2\ \mu$  in diameter. If the pore filling found in the loose slab has passed through the stages of cementation represented by the lower layers, A to C, the rind of acicular calcite must be a secondary recrystallization feature.

The more complete filling of pores near the surface correlates with the common observation that beachrock is much harder at its exposed surface than at a depth of only an inch or two. An evaluation of the degree of cementation of beachrock at depth was made in the bay just west of Kahuku Point on Oahu. In this area, beachrock is especially well exposed (Fig. 4) because of retreat of the beach, probably due largely to sand removal by man. At least seven distinct layers of

beachrock are present, some of which contain slabs reworked from older layers. Inspection of the exposed portions showed that the lower layers are less well cemented than the upper ones. The hardness of each layer was determined semiquantitatively by measuring the depth that a drill rod could be driven by 50 blows of a 16-pound sledge hammer (Fig. 5). Each layer was found to be slightly harder at its top surface than at depth. A deep hole, starting in Layer G, showed variations in driving rate correlative with the variations measured at the surface for the respective layers. The lesser resistance to driving found at depth also correlates with layers of poor cementation as judged from outcropping edges. Increased resistance at the bottom of the hole was probably due to entry into underlying reef rock. Similar results were obtained in another deep hole started in Layer C. Decrease in cementation at depth is also



FIG. 3. Whaleback of beachrock at Keaau, Oahu, with two interbedded layers of red alluvium.





FIG. 4. Layered beachrock dipping seaward at west side of small bay west of Kahuku Point, Oahu. Note reef rock on left against which beachrock abuts. Site of measurements diagrammed in Figure 5 is at left center.

well shown in the walls of a large drainage ditch cut through 5 feet of beachrock at Waieli on Kauai.

The characteristically poorer cementation at depth leads to ease of undercutting and movement of large slabs by waves. A slab near Kahuku Point on Oahu weighing probably 15 tons may have been overturned by the tsunami of 1946 (Fig. 6). Solution basins have just begun to form on the exposed bottom. Other areas having numerous loose slabs are Barbers Point, the beach a mile south of Waianae, and Makua on Oahu; Nohili on Kauai; and Hale o Lono on Molokai. At Nohili, erosion of soft material from beneath beachrock has allowed large slabs to slump to a position several feet below low tide level. The loose slabs are generally much harder than beachrock *in situ*, probably because cementation has proceeded from both top and bottom. When struck with a hammer the most firmly cemented slabs ring like gongs.

#### Surface

The surface of poorly cemented beachrock is rough, granular, and friable. That of well-

cemented beachrock, however, is hard and becomes modified by at least four separate processes: polishing and film formation, discoloration by boring blue-green algae, biochemical solution, and abrasion.

Polishing of the surface is fairly common. In part, it is produced by continual washing of sheets of calcareous sand across the rock. It is present, therefore, chiefly where thin patchy sands overlie the beachrock. Cross sections of truncated shells, coral and other recognizable organic debris show on the surface. Polishing is supplemented by deposition of a film of very thinly laminated aragonite on the surface, which, as at Bikini (Emery, Tracey, and Ladd, 1954: 46, pls. 42, 43), fluoresces a bright reddish-orange under ultraviolet light. The film is especially well shown on beachrock at Nanakuli and on basalt at Mauna Lahilahi (about 1½ miles southeast of Makaha) on Oahu, on beachrock at Nohili on Kauai, and on beachrock at Kepuhi on Molokai. Especially at Nanakuli (Fig. 7) and Nohili the film appears to constitute a form of case-hardening that resists the development



of solution basins. Some of the loose sands, such as Oahu sample 4 and Maui sample 1 of Table 1, are also highly polished and contain many grains which fluoresce. Illing (1954: 69) has noted similarly polished and coated sand grains on Bahaman beaches.

The second process that modifies the surface of hard beachrock is a darkening that is produced by activities of boring blue-green algae. In general the rock surface is a dull medium-to-dark gray, but at a few sites it is bright blue. Among the latter sites are Kawela Bay, Barbers Point, and Nanakuli on Oahu, and Kepuhi on Molokai. A piece of coral embedded in beachrock at Barbers Point

was examined by Dr. Maxwell S. Doty of the University of Hawaii, who found *Entophysalis crustacea* and *Galothrix* living at the surface. For ¼ inch beneath the surface there was a succession of colored bands that Doty ascribed to natural chromatography of plant pigments and their decomposition products. The bands and their probable composition are as follows, from the surface inward:

- blue—phycocynin
- pink—phycoerythrin
- clear
- yellow—a carotinoid
- green (thickest)—chlorophyll
- Small pink or green spots at the sides of

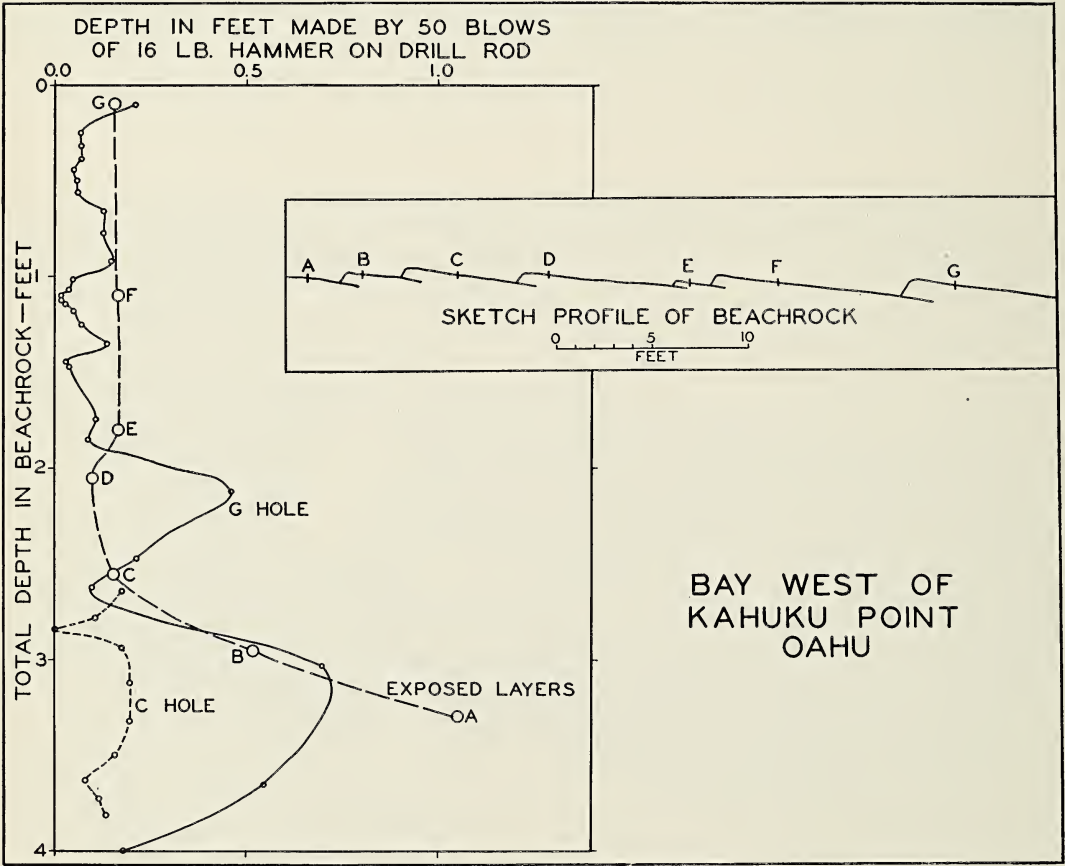


FIG. 5. Semiquantitative measurement of rock hardness, or degree of cementation, as determined by depth to which a drill rod could be driven by 50 blows of a sledge hammer. Line with long dashes shows measurements for exposed edges of layers. Solid line shows variation of hardness with depth in a hole driven vertically through all layers. Line with short dashes shows variation in a hole through three lowest layers.

TABLE 1  
CHARACTERISTICS OF BEACH SANDS

LOCATION	MEDIAN DIAMETER MM.	SORTING COEFFICIENT	RESIDUE INSOLUBLE IN DILUTE HCl PER CENT BY WEIGHT	COMPOSITION OF CALCAREOUS PORTION (Per cent by Weight)					
				Foram- inifera	Shells	Fine debris	Halimeda debris	Coral	
									Calcareous algae
Oahu									
1. 5 mi. E Kaena Pt.....	0.56	1.16	30	15	30	0	0	25	30
2. 1½ mi. W Mokuleia.....	0.98	1.29	5	25	35	0	0	10	30
3. Waimea Bay.....	0.73	1.33	5	40	40	0	0	5	15
4. 1 mi. E Waimea.....	2.10	1.50	0	2	55	0	0	5	38
5. ½ mi. S Laniloa Pt.....	0.38	1.44	5	5	40	20	0	5	30
6. E side Kualoa Pt.....	0.56	1.32	2	10	35	0	0	5	50
7. N Kaneohe Bay.....	0.18	1.69	99						
8. ¼ mi. N Kapoho Pt.....	0.67	1.31	8	35	35	0	0	5	25
9. Kailua.....	0.58	1.54	1	15	30	0	0	5	50
10. 1 mi. S Kailua.....	0.22	1.22	45	10	25	50	0	5	10
11. Waimanalo.....	0.31	1.13	1	20	40	10	0	10	20
12. Hanalei Bay (E Koko Head).....	0.63	1.47	98						
13. 2 mi. NW Koko Head.....	0.34	1.33	2	10	35	10	0	5	40
14. S side Diamond Head.....	0.62	1.29	30	10	30	0	0	20	40
15. W Ewa Beach.....	0.83	1.73	5	15	35	0	0	5	45
16. ½ mi. N Nanakuli.....	0.58	1.45	2	30	25	0	0	5	40
17. 1 mi. S Makaha.....	0.55	1.70	1	60	25	0	0	0	15
Kauai									
1. Haena.....	1.30		5	60	20	0	0	0	20
2. Hanalei Bay.....	0.20	1.53	80						
3. Kapaa.....	0.58	1.36	1	1	20	0	0	20	59
4. 3 mi. SE Waili.....	0.28	1.43	0	5	15	0	0	25	55
5. Waili.....	0.22	1.35	0	5	40	0	0	20	35
6. 4 mi. NE Nohili.....	0.40	1.30	10	5	15	0	0	35	45
Molokai									
1. 2 mi. S Kepuhi.....	0.45	1.19	5	50	20	0	0	0	30
2. Halawa.....	0.29	1.22	70	40	45	0	0	5	10
3. 5 mi. SW Cape Halawa.....	0.18	1.21	97						
4. 4 mi. E Kaunakakai.....	0.37	1.23	90	10	45	0	0	5	40
5. 1 mi. W Kaunakakai.....	0.23	1.61	75	10	65	0	0	10	15
Maui									
1. 2 mi. S Makena.....	0.41	1.50	1	60	20	5	0	0	15
2. 5 mi. S Kihei.....	0.19	1.16	10	10	40	40	0	0	10
3. 5 mi. SE Lahaina.....	0.23	1.20	95						
4. 2 mi. N Honokowai.....	0.76	1.49	40	50	35	0	0	0	15
5. Lower Paia.....	1.10		5	5	20	10	0	25	40
Hawaiian Islands average (33).....	0.54	1.38	29	21	33	5	0	9	32
Guam average (11).....	0.45	1.41	9	8	29	2	6	36	20
Bikini average (30).....	0.87	1.51	0	26	9	4	2	28	31





FIG. 6. Large overturned slab of beachrock  $\frac{1}{2}$  mile east of Kahuku Point, Oahu, estimated to weigh about 15 tons. Solution basins have begun to form on the now exposed bottom.

boulders and in some solution basins are evidently the result of natural removal of the original, outer, colored layers. A brief description of these algae and their effect in coloring the surface of limestone has been given by Newhouse (1954). As pointed out by Cloud (1952: 28, 29) blue-green algae also invade the surface layer of loose beach sand, where they make a thin green layer and provide a weak form of cementation.

The remaining two surface processes, solution and abrasion, develop larger erosional features that have been well described by Wentworth (1944). Most common are basins



FIG. 7. Solution basins in beachrock having a case-hardened surface formed by deposition of a thin film of calcium carbonate at a place  $\frac{1}{2}$  mile north of Nanakuli, Oahu.

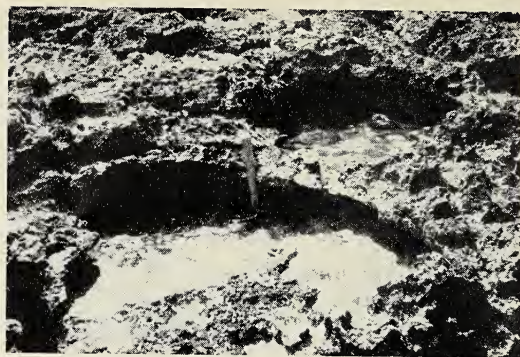


FIG. 8. Solution basins in reef rock  $\frac{1}{2}$  mile north of Mauna Lahilahi, Oahu. The reef rock surface is seen to be typically rougher than that of beachrock.

produced through solution of calcium carbonate by sea water trapped in pools (Fig. 8). This process is a complicated one and, as it is described rather fully by Revelle and Emery (in press), it will not be discussed here except to point out that solution basins are best developed and have sharp serrated edges in well-cemented beachrock (Layer G of Fig. 5, for example), they have rounded edges in moderately cemented beachrock (Layer F), and they do not exist in poorly cemented beachrock (Layers A to E). Their absence in poorly cemented beachrock is the result of high permeability that allows the pools to drain before much solution can occur. Solution also has produced water-level terraces that usually are divided by narrow low ridges into a series of rimmed pools (Fig. 9). These terraces and rimmed pools are common in reef rock of all the islands (Wentworth, 1939) but were noted in beachrock only at Nohili on Kauai, and at Hale o Lono on Molokai.

In contrast to the roughly circular form of solution basins, there are channels that are elongate and extend down the slope of the beachrock. These features have smooth, straight sides, and they quite evidently are produced by mechanical erosion along joints or other discontinuities through movement of sand or pebbles by wash of waves. Intermediate between the solution basins and the channels are potholes produced through me-



chanical abrasion by one or more cobbles that happen to become trapped in solution basins or other depressions in the beachrock.

#### *Relationship to Beaches*

In the Hawaiian Islands the maximum range of the tide is about 3 feet. Waves wash the beaches to a level ordinarily 2 or 3 feet higher than high tide. Little of the beachrock extends higher than the top of the wave-washed zone, but in several places it extends as much as 3 feet below low tide (west of Kahuku Point and at Hauula on Oahu; Nohili on Kauai; and Spreckelsville and Honokowai on Maui).

Most beachrock occurs on sandy beaches, usually with the same strike and dip as the layers of loose sand (Fig. 4). No beachrock was found at the ends of rocky points that project seaward between beaches, probably because of lack of sand.

In several places the beachrock, though at about the same height as the beach, has a different position in plan. The most conspicuous difference is shown by spits of beachrock that curve seaward away from the present beach, such as one at a point 1½ miles west of Mokuleia on Oahu (Fig. 10), and near Honokowai and at five places between Kahului and lower Paia on Maui.



FIG. 9. Rimmed terraces in beachrock at Nohili, Kauai. Note narrow anastomosing ridges that separate the pools of different levels. These consist of beachrock, showing that the rimmed terraces are erosional rather than built up by deposition. Beachrock extends several feet, at least, below low water.



FIG. 10. Curved spit of beachrock near Mokuleia, Oahu, showing that considerable retreat of beach sand in background has occurred since the time of cementation of the beachrock.

More common are "whalebacks," or anticline-like masses of beachrock located immediately off the beaches. In these the strike parallels the beach, but the layers dip seaward and landward on opposite sides. Such whalebacks were observed at Paumalu, south of Laniloa Point, Keaau (Fig. 3), Makua, and 4 miles east of Kaena Point on Oahu. An intermediate feature, massive seaward-dipping beachrock that forms a sort of offshore bar, occurs at Waieli and Nohili (Fig. 11) on Kauai. In many of these and other localities, the beach has obviously undergone large recent losses of sand owing either to natural causes, or to mining by man, or to both. Retreat of some beaches is also shown by recent undercutting of trees, by exposure of very soft beachrock at the back of beaches, and by historical records.

Along the coast of Oahu from 1 to 3 miles east of Kaena and at Diamond Head, beachrock is present but present-day beaches are either absent or are very small. East of Kaena, at Waimea, and on both sides of the point 2 miles south of Makaha, small patches of beachrock lie atop reef rock that has been raised 5 to 7 feet above mid-tide. These patches have sufficient horizontal extent to differentiate them from sands that have accumulated in small pockets of reefs as shown in the raised algal reefs at Waimea on Oahu. South of Laniloa Point and elsewhere, massive





FIG. 11. Bar-like ridge of seaward-dipping beachrock just beyond beach of loose sand at Nohili, Kauai.

beachrock overlies reef rock and reaches as much as 10 feet above mid-tide. At Kaena Point a Pleistocene shoreline 95 feet above sea level (Stearns, 1935) is marked both by reef rock and by about 13 feet of beachrock. Raised reef rock capped by beachrock was observed on none of the other three islands.

In summary, the position and attitude of most beachrock is closely accordant with present beaches, but some beachrock is discordant with present beaches owing to retreat of beaches, or to coastal elevation or submergence after the beachrock was formed.

DISTRIBUTION AND HYDROLOGY

*General*

The shores of Oahu were examined more thoroughly than those of Kauai, Molokai, and Maui, because beachrock is more abundant and the shores are more easily accessible. After experience had shown the rarity of beachrock at the ends of rocky points, most

of the effort was spent on sandy bays between points. Altogether about 190 stations were made along the shores of Oahu, 100 on Kauai, 40 on Molokai, and 70 on Maui. Hawaii was not examined because beaches are rare and consist mostly of noncalcareous sand. Although Midway Island was not visited, Mr. J. A. Neff of the United States Fish and Wildlife Service (personal communication) reported the presence of slabby rock on Eastern Island that probably is beachrock. The results of the survey, based on measurements from the plottings on topographic maps, are presented in Table 3. Simplified plots for each of the four islands are given in Figures 12, 14, 16, and 17. Where no indication of beachrock or beach sand is given, the area was either not visited or was considered an impossible site for beachrock because of the absence of a sand beach.

It seems advantageous to describe very briefly the hydrology of the Hawaiian Islands because of the hypothesis that the development of beachrock is in some way controlled by the outflow of ground water through beaches. The hydrology of the four islands on which beachrock was studied is generalized in Figure 18.

The Hawaiian Islands consist of volcanic mountains built predominantly of basaltic lava flows and extending to heights of from 1,000 to 13,000 feet above sea level. Rainfall on these mountains is heavily influenced by the degree to which the moisture-laden winds, particularly the northeast trades, are forced upwards in their passage over or around them.

TABLE 2  
COMPOSITION OF THIN-SECTIONS OF BEACHROCK SHOWN IN FIGURE 4

	PERCENTAGE OF AREA OF THIN-SECTION			PERCENTAGE OF ORIGINAL PORE AREA NOW FILLED
	Grains	Pore filling	Empty pores	
Loose slab.....	66	26	8	76
Layer G.....	57	33	10	77
Layer C.....	59	23	18	56
Layer B.....	56	15	29	35
Layer A.....	63	11	26	31

TABLE 3  
GEOGRAPHICAL DISTRIBUTION OF BEACHROCK IN HAWAII

COAST	TOTAL MILES OF COAST	MILES OF SANDY BEACH EXAMINED	MILES OF BEACHROCK	PERCENTAGE BEACHROCK OF SANDY BEACH EXAMINED	PERCENTAGE BEACHROCK OF TOTAL COAST
Oahu					
Mokuleia to Paumalu.....	13.6	4.0	0.1	2	
Paumalu to Makahoa Pt.....	10.4	6.0	4.9	82	
Makahoa Pt. to Mokapu Pen...	33.6	20.8	1.0	5	
Mokapu Peninsula.....	11.2	1.7	1.5	88	
Kapoho Pt. to Waikiki Beach...	31.4	16.5	1.3	8	
Waikiki Beach to Pearl Harbor...	19.5	0.0	0.0?	0	
Pearl Harbor to Mokuleia.....	42.5	24.0	12.0	50	
Total.....	162.2	72.0	20.8	29	13
Kauai					
3 miles NE Nohili to Kealia....	47.4	10.2	2.6	25	
Kealia to Waimea.....	46.5	12.4	2.6	21	
Waimea to 3 miles NE Nohili...	16.6	13.0	2.6	20	
Total.....	110.5	35.6	7.8	22	7
Molokai					
4 miles E Hale o Lono to Kepuhi	15.2	7.5	4.8	64	
Kepuhi to Cape Halawa.....	50.9	0.0	0.0?	0	
Cape Halawa to 4 miles E Hale o Lono.....	38.2	9.0	0.0	0	
Total.....	104.3	16.5	4.8	29	5
Maui					
Maliko Bay to Makena.....	84.2	0.0	0.0?	0	
Makena to Lahaina.....	31.5	10.5	0.0	0	
Lahaina to Kahului.....	34.0	7.3	1.6	22	
Kahului to Maliko Bay.....	11.1	6.6	1.7	26	
Total.....	160.9	24.4	3.3	14	2
Grand Total.....	537.9	148.5	36.7	25	7

In areas of maximum rainfall, located on the windward slopes of the higher mountains and at the crests of the lower mountains, the mean annual rainfall is commonly in excess of 200 inches per year. On the leeward slopes the rainfall is generally much less than on the windward slopes, and on the lower parts of leeward slopes the mean annual rainfall may be less than 20 inches per year. The wide geographic variation in rainfall creates wide variations in both surface-water and ground-water resources.

There is surface runoff from all except the youngest terrains formed by fresh porous lava

flows. The courses of the streams are, however, so steep and short that the runoff alone creates flashy and, in the low rainfall areas, infrequent flows. However, many streams have cut valleys sufficiently deep to tap ground-water bodies that are perched on layers of comparatively low permeability interbedded in the generally highly pervious lava flows or are impounded between intrusive bodies in the central areas of the volcanoes, and have thereby developed perennial flows from springs. Much of the portion of the rainfall that infiltrates the surface does not reappear in high-level springs, but descends





FIG. 12. Distribution of beachrock on Oahu.

to sea level in the lavas where it accumulates to form lenses of fresh water floating on the denser salt water penetrating from the sea. The thickness and freshness of these lenses depends in part on the amount of infiltration they receive and in part on the ease with which the water in them can drain seaward. Where the lavas crop out at the coast line there is generally easy outflow, and the lenses are thin. Particularly on the older islands, however, there may be extensive coastal plains underlain by prisms of sediments, partly coral and other limestones of generally high permeability, but also partly muddy sediments whose permeability is much lower than that of the lavas. Such sedimentary prisms constitute barriers restricting or diverting the ground-water outflow and causing the fresh-water lenses to be thicker in the bedrock behind such coastal plains.

### *Oahu*

The northwestern coast of Oahu, from Mokuleia to Paumalu, is low, and two of the island's largest rivers enter at Waialua and Waimea Bays. Ground water stands comparatively high in the bedrock lavas behind the coast, except in a stretch a couple of miles each side of Waimea Bay, its height indicating that its drainage seaward is restricted by the sediments that make up the coastal plain. Springs create swamps on parts of the plain, and some of the drainage of these swamps may take place diffusely through the beaches, though the largest outflows are probably by way of the rivers and a few springs at or below sea level. Beachrock was found at only one locality (Fig. 12), not near a spring, where it dips seaward in the wave-washed zone.

The northern shore, backed by a wide limestone plain from Paumalu to Makahoa Point,

is characterized by an almost continuous strip of beachrock interrupted by a few sand-free projecting points. Within the bays, beachrock forms seaward-dipping strata as much as 4 feet thick atop reef rock (Fig. 4), though locally the beachrock is so thin that reef rock projects through it. The contact between reef rock and beachrock is commonly near the mid-tide level (Fig. 13). In most of this area the beachrock is in the wave-washed zone; but just east of Kahuku Point it rests on reef rock reaching to 5 feet above mid-tide, and just west of Kahuku Point it extends a foot or two below low tide. As it does farther west, the ground water stands high in the bedrock lavas back of this northern shore, and again leakage from the bedrock creates swamps and ponds in the limestone plain. The points of seaward drainage from these swamps are not known, but there are no conspicuous springs at or above sea level. No perennial streams reach the shore in this stretch of the coast.

Eastward from Makahoa Point the coastal plain narrows and is broken by stretches where bedrock lavas crop out at sea level. At such places there must be outflow of ground water, and at a few places there are visible springs at or just above sea level. The mountain rainfall increases eastward, the valleys are more deeply incised, and a number of perennial streams reach the shore between Makahoa Point and the base of Mokapu Peninsula.



FIG. 13. Contact of beachrock atop reef rock near mid-tide level at a place one mile east of Kahuku Point, Oahu.

This shore contains little beachrock. Most of that which is present occurs between Laniloa Point and Hauula, where it forms thin seaward-dipping beds in the wave-washed zone except in the middle of the area where it rises from below mid-tide to 8 feet above mid-tide and is overlain by hard eolianite. About 1 mile south of Laniloa Point poorly cemented eolianite occurs at the base of a 10-foot cliff cut in dune sand. Beachrock was not found within Kaneohe Bay, an area of dilute sea water with many fish ponds along the shore. Islands within the bay are free of beachrock, perhaps because of the absence of loose sand, and, in the case of Coconut Island, because of artificial shores.

The Mokapu Peninsula consists of a core of late, relatively impervious, volcanic rocks and a surrounding limestone plain. The rainfall is low and there are no streams and probably very little ground water. Along shores on the eastern side of the peninsula there are extensive and massive beds of beachrock dipping seaward. Most of the beds are in the wave-washed zone, but near Ulupau Head some of the beachrock atop reef rock reaches to 10 feet above mid-tide. At Kapoho Point the reef rock is overlain by eolianite that has been truncated and drilled by potholes that later became filled by alluvium.

Over the eastern end of Oahu the rainfall decreases again, and no perennial streams drain to the coast east of Waimanalo and Honolulu. The permeability of even the bedrock is low in Kailua and Waimanalo on the windward side of the island, and although ground water stands relatively high in places, the amount of flow is probably not great. In the Honolulu area there are well-developed ground-water bodies in the bedrock whose seaward drainage is so restricted by coastal-plain sediments that most of the outflow probably takes place laterally to the coast through a limestone plain east of Diamond Head, and to Pearl Harbor, at the head of which there are very large springs. Makapuu Head is a mass of bedrock lavas cut into



cliffs at sea level. The rainfall is so low there, however, that there is probably very little ground water. Koko Head and Diamond Head are pyroclastic cones of low permeability and probably contain negligible ground water.

The shore of the southeastern part of Oahu from Kapoho Point to Waikiki Beach is mostly free of beachrock, although sandy beaches are abundant. Beachrock occurs in small thin patches near Kailua, northwest of Makapuu Head, near Koko Head, and around Diamond Head. At Diamond Head it lies atop a tuff terrace and beneath talus and eolianite in areas now free of loose beach sand. In all the areas except the one northwest of Makapuu Head, the beachrock is in the wave-washed zone; at this one place, a 1-foot layer of beachrock atop reef rock reaches to 8 feet above mid-tide.

Between Waikiki and Barbers Point, leakage from well-developed ground-water bodies in the bedrock lavas and seepage from streams have created thin fresh-water lenses in, and swampy spots on, the surface of the coastal plain, much of which is composed of limestone. No notable shoreline springs are known, however, except the Pearl Harbor springs previously mentioned, which represent drainage direct from the bedrock. From Barbers Point northwest to Makaha the bedrock ground-water bodies are less well developed because the rainfall is much lower. There are still thin lenses of ground water in the coastal-plain sediments as far as Makaha, at least, but again no notable shoreline springs are known. No perennial streams reach the shore. The Kaena Point area at the western end of the island is very dry.

Shores between Waikiki Beach and the entrance of Pearl Harbor are so altered by man that they were not investigated. Beginning at the entrance of Pearl Harbor and extending around Barbers Point and Kaena Point to Mokuleia, the coast is dominated by beachrock except at projecting sand-free points. Between the entrance of Pearl Harbor and

Barbers Point beachrock alternates with loose sand, with a general westerly increase in abundance of beachrock. Where present, the beachrock is restricted to the wave-washed zone. The 4-mile stretch of coast northwest of Barbers Point and the 5-mile section southeast of Kaena Point were not visited because of the lack of roads. Lava reaches the shore most of the way in the latter stretch (Wentworth, 1938: 8). Along most of the rest of the Waianae shore, beachrock is almost continuous except on the projecting points. The beachrock is almost equally divided between massive beds in the wave-washed zone (Fig. 2) and thin patches atop reef rock to heights of 5 to 8 feet above mid-tide. At Keaau it is interbedded with alluvium (Fig. 3). About half of the shore of abundant beachrock is backed by a wide limestone plain (Fig. 12), but in the northern part, from Keaau to Makua, only the beach separates the lavas from the sea.

### *Kauai*

The island of Kauai has had a more complex structural history than the other Hawaiian Islands. As a consequence, the permeability of its rocks is in general lower and the amount of ground water smaller in relation to surface water.

The western half of the northern coast, from 3 miles northeast of Nohili nearly to Haena Point, consists of cliffs cut into bedrock lavas and is inaccessible except by foot or boat. Sand beaches are rare and no beachrock has been found.

Most of the rest of the northern coast, the eastern coast, and the southern coast to Waiimea, consist of gentle slopes or low cliffs cut in relatively late lavas of generally low permeability. Numerous perennial streams reach the sea, and beaches at their mouths are common. In addition, there is a narrow coastal plain extending with minor breaks for about 5 miles south from Kapaa. Southwest of Nawiliwili Bay for 5 miles the coast consists of cliffs similar to those of the northwestern

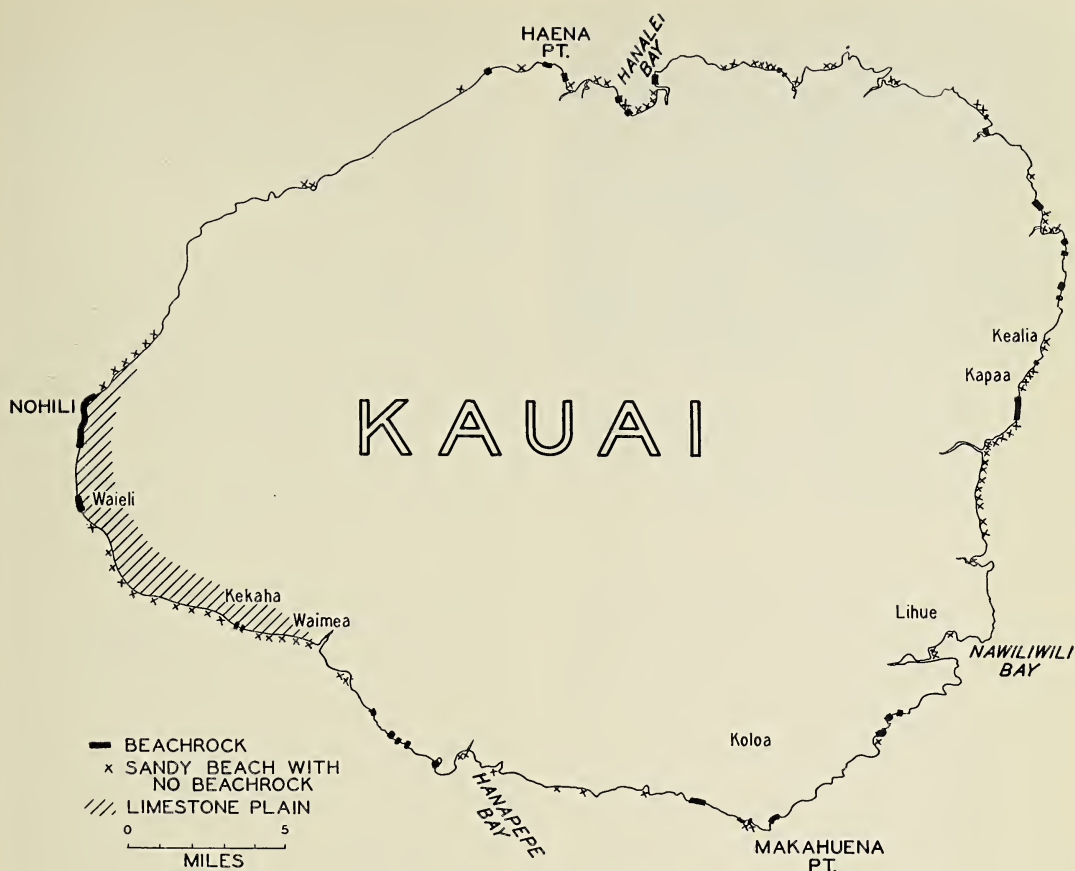


FIG. 14. Distribution of beachrock on Kauai.

coast. Beachrock is present in many small patches along these coasts, none more than 0.3 mile long (Fig. 14) and all consisting of thin seaward-dipping beds in the wave-washed zone. About a half dozen occurrences between Haena and Kealia are at the mouths of small to moderately large streams, in contrast with the absence of beachrock in such places on Oahu.

The western coast, between Waimea and a point 3 miles northeast of Nohili, is backed by a limestone plain that reaches a width of 2 miles. The surface of the plain was once largely covered by a swamp fed by intermittent streams and by leakage of ground water from the bedrock lavas in cliffs back of the plain, but the swamp has been artificially drained.

Along the seaward margin is a wide high sandy beach locally backed by dunes. A local fisherman reported that the northernmost part of the beach has become considerably wider in the past few years and in this area no beachrock is exposed. The escape of fresh ground water through the beach sand is notable 3 miles northeast of Nohili, where the coastal plain pinches so that the beach rests directly against the bedrock cliff. In the middle of the area, at Nohili, there is a 2-mile exposure of massive beachrock (Fig. 11) reaching about 4 feet above mid-tide and at least 3 feet and possibly 8 feet below mid-tide. The uncertainty is due to slumping of large blocks of the beachrock due to the erosion of some undetermined softer material





FIG. 15. Beachrock at Nohili, Kauai, showing solution basins having rounded and smoothed surfaces believed to indicate modification of ordinary sharp-edged solution basins during a period of burial under loose beach sand followed by exhumation.

underlying it. The slumped blocks range up to 30 by 15 by 5 feet. A shorter exposure of beachrock at Waieli has been transected by a drainage ditch that reveals progressive decrease of cementation of the beachrock at depth. Some of this beachrock has a rounded and smoothed surface (Fig. 15), unlike beachrock elsewhere which is undergoing active solution. This is presumed to indicate a former exposure of the beachrock followed by burial under thick sand, and finally exhumation by recent retreat of the beach. Judging from the massive nature of beachrock at both Nohili and Waieli, it seems likely that this entire section of the western

coast is underlain by beachrock that now is exposed only where recent retreat of beach sand has occurred. Retreat of the beach has also exposed very poorly cemented beachrock and eolianite landward of the main mass of beachrock at Nohili.

### *Molokai*

The eastern part of Molokai has a high rainfall, and is well drained by both surface streams and ground-water flow. Particularly along the southern coast a few miles south of Cape Halawa to a few miles west of Kaunakakai the escape of ground water at sea level is notable. The western part is very dry with no perennial streams and only brackish ground water.

Beachrock on Molokai is confined to the southwestern and western coasts, from a point 2 miles east of Hale o Lono to Kepuhi (Fig. 16). A 4-mile continuous exposure of beachrock, the longest seen in the islands, centers at Hale o Lono. Within the wave-washed zone and seaward-dipping, most of this beachrock is slabby and some of it has been quarried for building purposes. In the area north of Laau Point beachrock is slabby like that at Hale o Lono, but it reaches to 8 feet above mid-tide. The bay near Kepuhi contains some of the most massive beachrock seen in the islands, reaching from below mid-tide to 10 feet above it. The surface is highly polished



FIG. 16. Distribution of beachrock on Molokai.

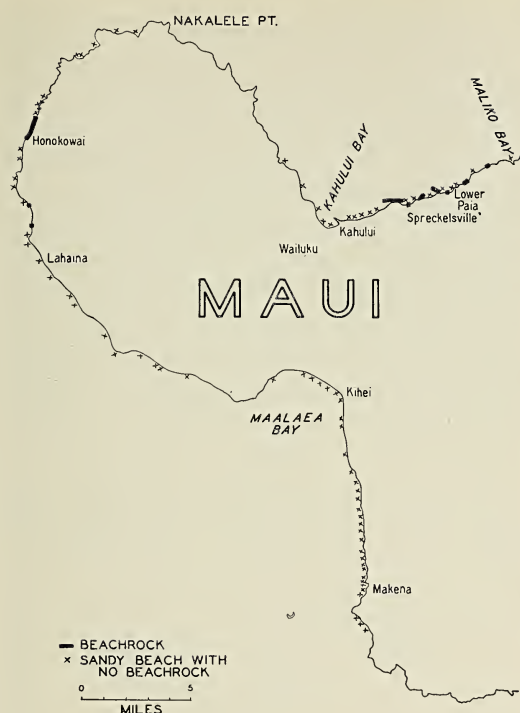


FIG. 17. Distribution of beachrock on Maui.

and locally is discolored by blue-green algae. Elongate erosional channels are well developed.

From Kepuhi around Ilio Point to Cape Halawa, the coast is precipitous with only two sandy beaches. At one of these places, Kalaupapa, possible but uncertain beachrock was noted from a vantage point at the top of the high cliff about 2 miles away. This is believed to be the only possible site of beachrock along the entire northern coast of Molokai. The southern coast from Cape Halawa to Hale o Lono was examined closely without finding any trace of beachrock. Scattered along almost the entire shore are artificial fish ponds in which mullet and other brackish-water fish are cultivated. Muddy sediments have accumulated along the more protected parts of this shore. *Ulva*, or sea lettuce, is very abundant along the shores, forming local drifts about a foot thick.

### Maui

Less beachrock was found on Maui than on any of the other islands examined, a total of 3.3 miles of shoreline length (Fig. 17). The absence of sand beaches around most of East Maui, from Maliko Bay to a point 2 miles south of Makena, means that the presence of beachrock is very unlikely, so the available field time was concentrated in more favorable areas.

No perennial streams reach the shores of East Maui from Kahului Bay to Maliko Bay except at Maliko, nor from Maalaea Bay to far east of Makena. However, east of the two bays, the bedrock lavas extend to the shores with only a thin discontinuous mantle of beaches, so that ground water escapes easily at or near sea level. On the southern coast the ground water is brackish and probably not plentiful, but there must be a substantial outflow along the northern coast. It is noteworthy that there is beachrock on the northern coast, but none on the plentiful beaches of the southern coast. The beachrock on the northern coast consists of an interesting series of five spits and bars, between Spreckelsville and Lower Paia, and occurrences in the wave-washed zone in two bays northeast of Lower Paia. In one of these bays and at the small point north of Spreckelsville beachrock overlies red soil, and at the latter site it also directly overlies a basaltic flow in places. More beachrock is shown in offshore positions in this area than elsewhere in the islands, and the remnants are also farther offshore, suggesting that retreat of sand beaches has been great. Recent retreat is also indicated by undercutting of trees and by historical records. Some of the sand may have been transported to the southwest and added to the beach near Kahului where no beachrock could be found, but additional sand has been removed for construction purposes. One of the beaches at Spreckelsville was covered with drifts of *Ulva*.

Narrow coastal plains, in which no beachrock was found, front Maalaea Bay and Ka-



hului Bay. Cliffs form the coasts of West Maui for 3 miles west of Maalaea Bay on the south, and from Kahului Bay around Naka-lele Point nearly to Honokowai on the north. The few sandy beaches on these shores do not contain beachrock.

The rest of the coast, on the west and southwest, consists of a narrow coastal plain. Judging from the low and fairly uniform height of the ground water in the bedrock back of the coastal plain, there must be fairly plentiful points of ground-water escape, but none are known at or above sea level. South of Lahaina there are no exposures of beach-rock, but 2 miles to the north there is a small outcrop and another mile farther north there

are loose slabs of beachrock. Near Honokowai beachrock in the wave-washed zone extends along more than a mile of shore, in some sections forming a spit or bar 20 to 50 feet offshore of the present beach. Locally, two bars are present. Along some of this shore, recent retreat of a 10-foot cliff of alluvium is indicated by undercutting of large trees, and this retreat is in part responsible for exposing some beachrock. Except for two small outcrops just north of Mahinahina Point, a mile north of Honokowai, beachrock is absent around the rest of West Maui.

AGE

In most areas the beachrock could have been formed very recently, even within the

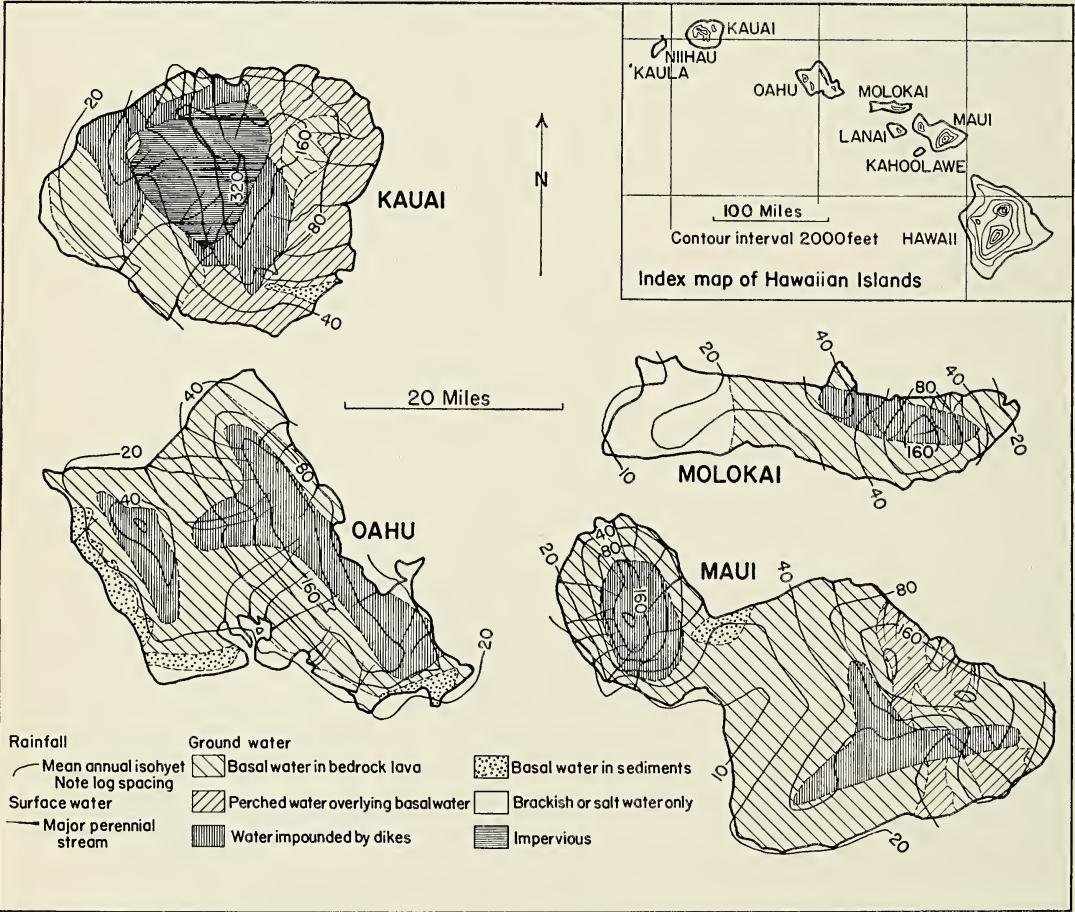


FIG. 18. Map showing hydrology of Kauai, Oahu, Molokai, and Maui.

last decade. A recent age is suggested by the common restriction of the beachrock to positions within the wave-washed zone and to the similarity of its strike and dip to those of the present beach. A somewhat greater age in other places may be indicated by differences in the positions of the beachrock and the present beach (i.e., presence of beachrock spits and whalebacks) indicating retreat of the beach since the beachrock was formed. A locally greater age is also indicated by interbedding of beachrock with other materials. Alluvium is interbedded or overlies beachrock at Waianae and Keaau on Oahu. Near Lower Paia on Maui beachrock rests on red soil that is now intertidal in position.

Some beachrock must be older, and of a greater age than nearby intertidal beachrock, for on Oahu it occurs on raised reef rock as much as 10 feet above present sea level. Elsewhere,  $\frac{1}{2}$  and  $2\frac{1}{2}$  miles south of Laniloa Point and at Diamond Head on Oahu, beachrock is overlain by eolianite, which at Diamond Head is itself overlain by talus. The greatest age of all, Pleistocene, is indicated for beachrock on the 95-foot Kaena terrace of Oahu.

In summary, beachrock in the Hawaiian Islands may be of three different ages: modern to a few thousand years old (wave-washed zone); probably several to many thousand years old (on raised reef rock and/or overlain by alluvium or eolianite); and Pleistocene age (Kaena terrace). In addition, it is evident that even the youngest of these three ages represents not a single stage of cementation, but rather several to many separate stages. Repeated stages of cementation are well shown by the common presence of reworked beachrock slabs incorporated in later layers and by truncation of earlier layers by later ones.

#### ECONOMIC VALUE

Beachrock of many tropical islands has long been used for minor construction purposes, such as grave markers and flagstones. Some has also been used to make "flint" artifacts.

Slabs of beachrock were quarried from near Hale o Lono on Molokai and transported to Honolulu for decorative use in buildings. It has also been quarried near Barbers Point on Oahu, according to Stearns (1939). Many other beaches are capable of supplying such slabs. From still other localities solid dimension stone, 2 to 4 feet in smallest dimension, can be obtained. Among the best of these localities are: bays on both sides of Kahuku Point, two areas just south of Laniloa Point, and two areas just south of Waianae on Oahu; at Waieli and Nohili on Kauai; and at Kepuhi on Molokai. The economic value, however, is not great because the cut stone probably would have an appearance very similar to concrete made from loose beach sand.

Beachrock has also been found to constitute the best source, on atolls, of aggregate for concrete. The rock is quarried, crushed, screened, and mixed with cement and sea water to form a good grade of concrete (Narver, 1954).

#### ORIGIN

The main purpose of this investigation was to discover, if possible, the origin of beachrock—at least of the beachrock in the Hawaiian Islands. Altogether, beachrock was noted along approximately 37 miles of the shores, but in such a variety of environments that it is difficult to isolate the least common denominator, or most probable controlling factor.

Absence of beachrock at the ends of points and other areas where loose beach sand is not now present, nor probably ever was present, leads to the obvious conclusion that loose beach sand must be available if beachrock is to form. Beyond this point, generalizations appear to have many exceptions.

Before making the present study, the authors recognized that beachrock is abundant around islets of atolls and relatively rare around high islands of moderately great rainfall such as Guam. The hypothesis was developed that beachrock occurs where the in-



terstitial water of beaches is sea water, which is already saturated with calcium carbonate, and that it should be absent where the interstices are occupied by ground water that has passed only through volcanic rocks and is presumably not saturated with calcium carbonate. In addition, beachrock should be present where the beach contains ground water that has escaped from a wide limestone plain and thus contains a high percentage of calcium carbonate. The basis for this hypothesis is that water that is left in the beach by a falling tide or that rises by capillarity through the beach sand largely evaporates near the sand surface. Any salts originally dissolved in the water are precipitated in the sand where they serve as a cement (Emery and Foster, 1948). Readily soluble salts such as sodium chloride are removed by the next high tide, but salts such as calcium carbonate may remain to form a more permanent cement. In addition, the heating of the beach by the sun during the day tends to reduce the solubility of  $\text{CO}_2$  in the interstitial water close to the surface, so that its pH rises. If the water is initially near saturation, calcium carbonate is precipitated (Emery, Tracey, and Ladd, 1954: 45-46). Because sea water contains more calcium carbonate than most ground waters, it seems reasonable to expect that beach sands would be cemented into beachrock more easily where sea water is evaporated than where only fresh water containing little calcium carbonate is evaporated.

On Oahu the hypothesis appears to be supported generally by field data. Beachrock is

abundant along the western coast where the rainfall is low and on Mokapu Peninsula, also a low rainfall locality. Conductimetric tests show that interstitial beach water in these areas is sea water; therefore, it is probable that little ground water escapes through these beaches. One of the chief areas of beachrock on Oahu is the northern coast around Kahuku Point, an area where considerable quantities of fresh water escape and where conductimetric and titration tests showed that ground water is associated with beachrock. Titration of four water samples from the bottom of the deepest hole of Figure 5, of three from the loose beach sand, and of three from the ocean water atop the reef flat, yielded average chlorinity values of 2.50, 3.58, and 19.14 parts per thousand, respectively. Comparison of the calcium and chloride concentrations (Table 4) shows that both ions are less abundant in water collected from the hole in beachrock than in sea water, but that the calcium concentration with respect to chloride is about twice as great as in sea water. This high ratio of calcium to chloride in the ground water means that much of the calcium must have been derived from the rocks through which the water passed. Some additional support for the hypothesis can be obtained by consideration of the areas where beachrock is absent. Very little beachrock occurs along most of the eastern coast of Oahu where high rainfall leads to escape of large amounts of surface and ground water. No beachrock whatever is known in Kaneohe Bay, where sea water was found to be diluted

TABLE 4  
COMPOSITION OF WATERS

	CALCIUM ppm	CHLORIDE ppm	Ca/Cl	SOURCE OF DATA
Hole through beachrock of Figure 5 . .	144	2,610	0.0552	USC analysis by Dr. Wilson Orr
Sea water (general) . . . . .	400	18,980	0.02106	Sverdrup, Johnson, and Fleming (1942: 173)
Sea water (Hanauma Bay) . . . . .	507	19,681*	0.0258	Stearns and Vaksvik (1935: 361)

\* Includes nitrate.

by fresh water escaping from volcanic rocks or flowing atop an alluvial plain.

On Molokai the distribution of beachrock fits the hypothesis even better. Beachrock is well developed along the western and south-western shores, where escape of ground water is probably small because the rainfall is low. Beachrock is absent along the rest of the southern shore. This coast, though itself low in rainfall, receives much ground water from the main ridge of East Molokai which has a high rainfall. Because of the considerable escape of ground water, the nearshore sea water has been diluted, especially in the large artificial fish ponds that were built in ancient times. Brackish water in these ponds supports a crop of mullet, a fish that prefers fresh or brackish water (Hiatt, 1944). In the same area *Ulva*, sea lettuce, is prolific (Abbott, 1947), suggesting that it too prefers dilute sea water. The only other areas of abundant fish ponds are along Kaneohe Bay and the southeastern shore of Oahu, and here also beachrock is absent.

On Maui a reversed situation exists. Beachrock is absent or rare around the leeward coast of low rainfall and probably little ground water, but abundant near Lower Paia where considerable dilution by ground water is known. In this area the ground water comes directly from the volcanic rocks to the beach, as it does along the southern shore of Molokai. Thus, on Maui the distribution of beachrock does not fit the original hypothesis.

On Kauai, as on Maui, beachrock appears to be independent of the kind of interstitial water. The most extensive area of beachrock is the western alluvial coast, a situation similar to the dry western coast of Oahu where beachrock is abundant. However, beachrock also occurs in small patches around other shores of Kauai, and some of these patches lie at the mouths of perennial streams.

Altogether, the evidence from distribution shows no unequivocal preference of beachrock for beaches having interstitial water composed of sea water, ground water from lime-

stone plains, or ground water from volcanic rocks. If the nature of the interstitial water were a dominant control, we must be prepared to say either that areas which now contribute much ground water directly from volcanic rocks formerly contributed little ground water, and that beachrock in those areas was formed during the past, or that details in the pattern of the ground-water flow, not predictable except possibly by a study more intensive than that reported, lead to important variations in the nature of the interstitial water in the beaches. The first conclusion does not appear to be reasonable, and the second begs the question. We must look, therefore, for other possible explanations or for supplementary factors.

One such explanation was proposed by Cloud (1952) who suggested that blue-green algae, known to live in the top quarter-inch of some beach sands, may cement the sand through their biochemical activities. Cementation of individual layers, 2 feet or more thick, appears to be a fatal objection, because the algae are probably restricted to the top-most fraction of an inch in order to receive enough sunlight for photosynthetic activities. Another possible explanation proposed by Nesteroff (1955: 33) and Ranson (1955) is that amorphous calcium carbonate is deposited between the sand grains by the action of bacteria living in organic material deposited with the sand. However, there seems to be no evidence of the presence of large amounts of organic material in the Hawaiian beachrock and the organic content of the sand is extremely low (Oahu samples 1, 5, 8, 15, and 16 of Table 1 have organic carbon percentages of only 0.10, 0.16, 0.14, 0.22, and 0.09, respectively).

Merrin (1955), who studied beachrock in Puerto Rico, proposed that beachrock is restricted to areas of stable beaches; however, many of the Hawaiian beaches having beachrock are known to undergo large changes seasonally and because of storms. In fact, some of the areas of beachrock on Kauai



shown by Figure 14 were covered by sand at the time of our mapping and were discovered by Dr. Douglas Inman of Scripps Institution of Oceanography during a later visit.

In short, although beachrock is abundant in the Hawaiian Islands and elsewhere, we do not know how it forms. Mapping its distribution is not by itself a sufficient source of data to solve the problem of origin. Perhaps the making of many additional chemical analyses of interstitial waters of beaches would be a helpful supplement to mapping.

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*Fritillaria arafaera* n. sp., a Form of the Sibling Species:  
*Fritillaria haplostoma*-Complex (Appendicularia: Chordata)

TAKASI TOKIOKA<sup>1</sup>

AN APPENDICULARIAN specimen found in one of the plankton samples hauled by Mr. Sagara in the Arafura Sea during the biological survey of the pearl oyster fishery ground seems to represent a new species, which is described here and named *Fritillaria arafaera*. The species is considered to show an extreme form of the sibling species forming the *Fritillaria haplostoma*-complex, in which *F. abjornseni* Lohmann and many of Essenberg's species are included. The latter are discussed taxonomically in the last part of the article.

*Fritillaria arafaera* n. sp.

**TRUNK:** This is a small species. Trunk is 440  $\mu$  in length and quite wide, being widest on the level of the posterior part of the oikoplast-epithelium and with the value of width/length about 0.4. The body is slightly bent ventrad at the insertion point of the tail, situated slightly posterior to the middle of the body. It is rather compressed dorsoventrally excepting the anterior one third of the trunk, where a remarkable hood is formed on the oikoplast-epithelium, the posterior margin of which almost reaches the anterior end of the stomach. The anterior half of the pharynx is fairly narrow, the upper lip is roughly triangular in outline and protruded anteriorly beyond the frontal end of the hood. Endostyle short, curved only slightly; a ciliated band encircles the buccal cavity on the level of the anterior end of the endostyle. Spiracles comparatively large, roundish in outline and well separated. Oesophagus short, stomach globular and with nearly smooth

surface. Intestine with three glandular appendages (gl. ap. 1-3, Fig. 1) arranged dorsoventrally, the middle one (gl. ap. 2, Fig. 1) much larger than the other two. This middle appendage assumes superficially a glandular appearance and it is treated here as a glandular appendage. However, it is possible that this is merely a part of the intestine proper. Ovary is spherical and testis is an elongate mass, genital region of the trunk is much shorter than the rest. Gland cells are distributed as follows: one at the posterior end of the testis, one at each posterolateral corner of the trunk, one at the outer side of each spiracle and one near each posterolateral edge of the hood.

**TAIL:** Tail is 1380  $\mu$  in length. Tail length/trunk length is 3.1. The proximal end of the tail fin assumes an appearance of sloping shoulders instead of angular shoulders frequently met with in common fritillarians. Musculature wide, but distally diminishing in breadth rather rapidly. Thus it is narrowed nearly to the breadth of the chorda in the posterior part, although it definitely reaches the distal end of the chorda. Width of tail musculature/tail length ( $\times 100$ ) is 11.8 and width of chorda/maximum width of tail musculature ( $\times 100$ ) is 17. The distal end of the tail fin is fringed with slightly thickened margin, this probably indicates the existence of cilia at this portion.

REMARKS

The present new species resembles most closely *Fritillaria abjornseni* Lohmann from the neighbouring waters of Fremantle and *Fritillaria lohmanni* Essenberg and *F. tereta* Essenberg from the San Diego region in smaller size of body and general appearance

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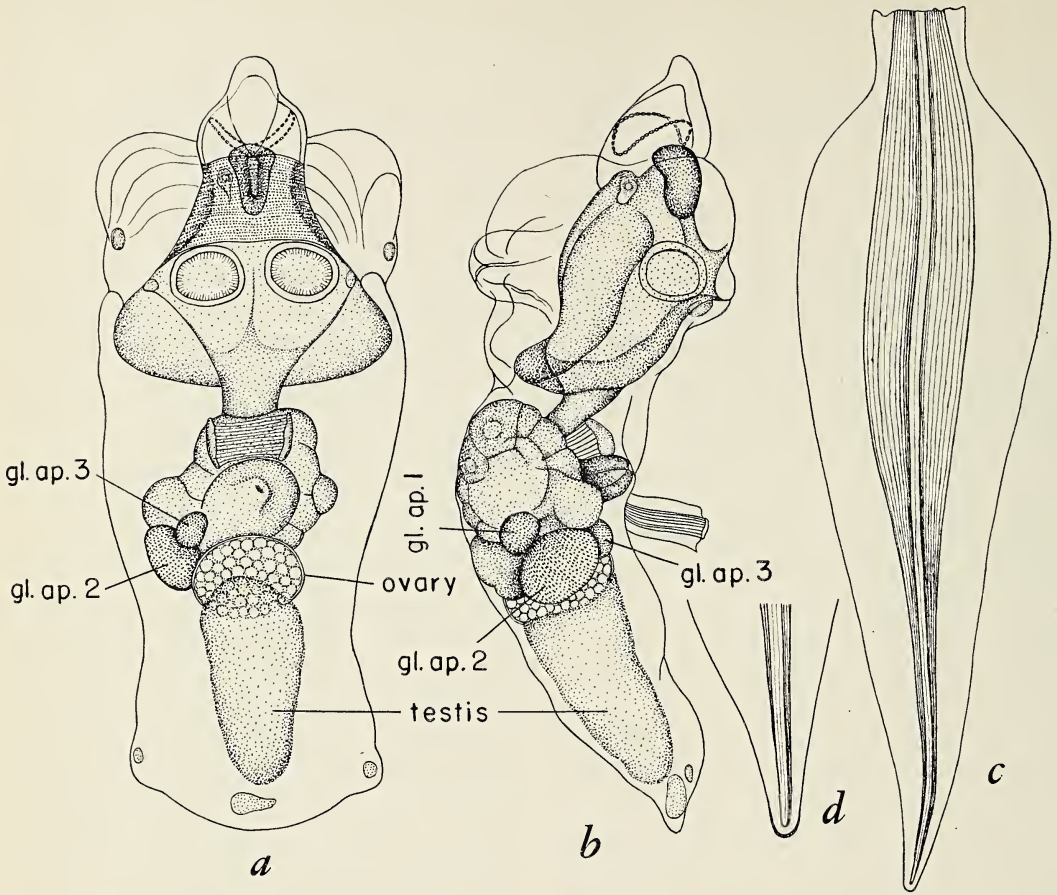


FIG. 1. *Fritillaria arafaera* n. sp.: a, Ventral aspect of trunk,  $\times 200$ ; b, right lateral aspect of trunk,  $\times 200$ ; c, tail,  $\times 73$ ; d, distal portion of tail,  $\times 200$ . gl. ap.—glandular appendage.

of both trunk and tail. It is especially related to *F. lohmanni* in that three glandular appendages are found on the intestine. In *F. arafaera*, however, the middle one of the three accessory blind sacs (= glandular appendages) may possibly represent a part of the intestine proper. In both of Essenberg's species, moreover, the trunk is much more elongate than in the present one and the distance between the posterior margin of the oikoplast-epithelium and the anterior edge of the stomach is much greater than in the Arafuran specimen. Thus, *F. abjornseni*, *F. lohmanni*, and *F. tereta* conform well to one another in that both spiracles are in contact with each other at the inner side, and this feature is con-

sidered by Lohmann (1909) as the critical characteristic of *Frit. abjornseni*. Consequently these three species are considered to be treated as forms belonging to a single species, the name of which should be *Fritillaria abjornseni* according to the law of priority. In the present species, however, the two spiracles do not touch as shown in Figure 1A. For these reasons, I prefer at present to treat the present specimen as a new species and name it *Fritillaria arafaera*.

As I stated previously (Tokiooka, 1951: 4), *F. haplostoma* shows a considerable range of variation in body length. Small specimens of *F. haplostoma* described in an earlier paper (Tokiooka, 1955: 259), smaller forms reported

in the same paper (p. 256) under the name of *F. abjornseni* and several forms allied to *F. haplostoma*, described by Essenberg (1926) under different names, seem to combine *F. abjornseni* with typical forms of *F. haplostoma* as far as body size is concerned.

Considering the structure of the trunk, the shape of the spiracles seems not to be accepted as an important characteristic, because it varies from elongate to round, correlated with decrease of body size. Even in large specimens, the spiracles may sometimes be roundish as they are indicated in the original figure by Fol (1872, pl. VI, fig. 6). The distance between the posterior end of the oikoplast-epithelium and the frontal edge of the stomach seems to diminish regularly according to the shortening of the trunk. The surface of the stomach may be considerably roughened by protrusion of some wall cells in some individuals although it is usually smooth in smaller specimens. The proportional length of the genital region diminishes with the decrease of the body length.

The tail of typical *F. haplostoma* is characterized by narrow musculature and exposed posterior portion of the chorda. The musculature

scarcely reaches beyond the lateral sides of the chorda in typical forms, but in some individuals, especially in smaller ones, it is slightly wider than the chorda. In *F. abjornseni* Lohmann (1909), C/M  $\times 100$  measured on his figure is 22.2, while it is 16.6 in *F. tereta* and 20.8 in *F. lohmanni* both also measured on figures. In specimens reported by Tokioka (1955) under the name of *F. abjornseni*, the value is about 33. It is 36.4 in *F. lucibila* Essenberg and about 50 in *F. limpida* Essenberg. These data seem to support the idea that the narrow tail musculature of typical *F. haplostoma* continues to the wider tail musculature of *F. abjornseni* through several intermediate forms. The exposed posterior portion of chorda is fairly long in typical forms of *F. haplostoma*, but it is extremely short in forms described by Tokioka (1955) under the name of *F. abjornseni*. Unfortunately, as no description is given about this feature on the type specimen of *F. abjornseni* and many forms reported by Essenberg, further consideration of this characteristic must be abandoned.

According to Lohmann (1909) the most important characteristics differentiating *F. ab-*

TABLE 1

TEN FORMS OF THE *Fritillaria haplostoma* COMPLEX GROUPED BY DIFFERENCES IN THREE CHARACTERISTICS  
(Values of width of chorda and maximum width of tail musculature in species of Lohmann and Essenberg were measured on published figures)

NAME OF SPECIES	LENGTH OF TRUNK	WIDTH OF TRUNK	CHORDA
		LENGTH OF TRUNK	$\times 100$ MUSCLE
Group I			
<i>Fritillaria lucibila</i> Essenberg . . . . .	850 $\mu$	0.16	36.4
<i>Fritillaria limpida</i> Essenberg . . . . .	700	0.2	50
Group II			
<i>Fritillaria campila</i> Essenberg . . . . .	550	0.2	31.8
<i>Fritillaria tacita</i> Essenberg . . . . .	500	0.2	26
<i>Fritillaria abjornseni</i> (described by Tokioka in 1955) . . . . .	440-740	0.25	33
Group III			
<i>Fritillaria amygdala</i> Essenberg . . . . .	340	0.33	22.7
<i>Fritillaria lohmanni</i> Essenberg . . . . .	370	0.16	20.8
<i>Fritillaria tereta</i> Essenberg . . . . .	400	0.25	16.6
<i>Fritillaria abjornseni</i> Lohmann . . . . .	250	?	22.2
Group IV			
<i>Fritillaria arafœra</i> n. sp. . . . .	440	0.4	17



*jornseni* from *F. haplostoma* are the smaller size, the spiracles touching each other at the inner side and the tail musculature being much wider than the chorda. In Table 1 I attempt to arrange various allied forms of *F. haplostoma* and *F. abjornseni* systematically on these standards.

Group I may safely be accepted as proper *F. haplostoma*, because the tail musculature is rather narrow and the spiracles are comparatively small and situated apart from each other. The four forms of Group III are undoubtedly united into a single species, *F. abjornseni*, because the tail musculature is very wide and both spiracles touch each other at the inner side. Group II is considered to involve intermediate forms between Groups I and III in the feature of the tail musculature. The spiracles are separated from each other, but they are comparatively large as in Group III, except in *F. tacita*. The exposed posterior portion of the chorda is extremely short in the last member of the group as compared with that in the typical form of *F. haplostoma*, and the distance between the posterior end of the oikoplast-epithelium and the frontal edge of the stomach is very slight in the last two of the group. For these reasons, I prefer to treat this group conveniently under *F. abjornseni*, by extending the definition of this species so as to include forms which have spiracles separated from each other. *F. arafuera* is characterized by a remarkably wide trunk, separated spiracles, wide tail musculature, basal part of the tail fin like sloping shoulders and absence of the exposed distal portion of the chorda, although it is closely related to *F. abjornseni*.

I am here placing the ten forms considered in the table into three species: *F. haplostoma*, *abjornseni* and *arafuera*. And it seems very reasonable to consider these three species as sibling species forming a *Fritillaria haplostoma*-complex, in which *F. magna* Lohmann and *F. aberrans* Lohmann may also be included when more abundant data concerning the feature of the alimentary organ are accumulated and considered carefully. However, the mechanism which causes this wide variation is still unknown. It is clear that both *F. abjornseni* and *F. arafuera* are found mostly in coastal waters and smaller forms of *F. haplostoma* are met with more frequently in coastal water rather than in the pure oceanic water. Lastly, the present new species certainly may be considered as being situated at the extremity of a wide range of variation, opposite to the typical *F. haplostoma*.

I wish to express here my hearty thanks to Mr. Sagara for his kindness in giving me a chance to examine the present precious material.

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## A New Gadiform Fish from the Continental Slope off Southeastern Australia

T. R. COWPER<sup>1</sup>

THE SPECIMEN which is here described was foul-hooked while longlining from the F.R.V. "Derwent Hunter" on the continental slope east of Tasmania in February 1953, and, although this area has been fished on a number of occasions subsequently, no further specimens have been taken. Unfortunately, as a result of being foul-hooked, the abdominal wall of the specimen was damaged; anteriorly below the origins of the pectoral fins and laterally on the left hand side, the former injury being apparent in Figure 1.

It is assigned to the genus *Lepidion* Swainson (1838) of the family Moridae because it exhibits the following characters: an elongate, compressed body; scales cycloid, covering whole of the body, head, and bases of fins; snout short and blunt in profile; maxilla extending to vertical below eye; barbel on chin; fine teeth in bands on both jaws; two dorsal fins narrowly separated; first dorsal fin with anterior ray filamentous and produced; anal fin single, deeply indented; caudal subtruncate; ventrals narrow, of seven rays, the two uppermost being long and filamentous. *Lepidion* was transferred from the family Gadidae to Moridae by Svetovidov in 1948.

Though this specimen has a number of characters in common with other members of the genus it has not been possible to relate it to any one of them. The characters which are recurrent in the majority of descriptions of members of the genus (Gunther, 1862, 1887; Johnson, 1862; Goode and Bean, 1895; Franz, 1910; Gilchrist, 1922; Barnard, 1925;

Tanaka, 1927; Svetovidov, 1936; Maul, 1952) have been selected for purposes of comparison in establishing this specimen as a new species.

*Lepidion microcephalus*, sp. nov.

Figs. 1, 2

Head comparatively small, being 5.75 in the total body length and 1.75 in the distance between the origin of the ventral fin and anus. Eye large, 3.125 in the head, 1.25 times the length of the snout, twice that of the barbel, and 1.66 that of the interorbital width. Maxilla extending below the anterior third of the orbit. Numerous fine teeth in bands on the premaxilla and mandible. Lower jaw shorter than the upper. Snout almost square in profile. Posterior nostril considerably larger than the anterior which has an elevated, semi-tubular border posteriorly. Greatest depth of body 5.25 in the total length and occurring below the 8-9th ray of the second dorsal. First dorsal fin of 5 rays, the anterior ray long and filamentous being 1.33 times the head length. Base of first dorsal equal to least depth of caudal peduncle. Second dorsal fin of 54 rays having its longest rays in the anterior half and in the posterior portion in the region of the 42nd ray. Ventral fins originating under the posterior 0.4 of the head, close together, having 7 rays, the upper two being long and filamentous, the lower of these being the longer. Length of ventral fin exceeds that of the pectoral. Pectoral fin of 21 rays, originating anterior to the vertical from the origin of the first dorsal and extending to the vertical below the 5th ray of the second dorsal. Anal fin of 46 rays, originating under the vertical from the 14th ray of the second dorsal, having

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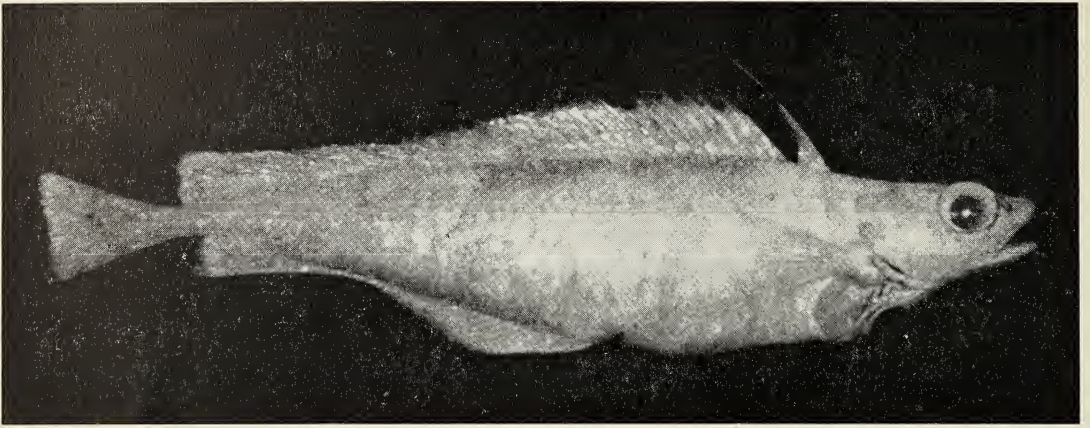


FIG. 1. *Lepidion microcephalus*, sp. nov. Holotype in Tasmanian Museum. Type locality: 12 miles east of Schouten Is., Tasmania, 400-420 fm.

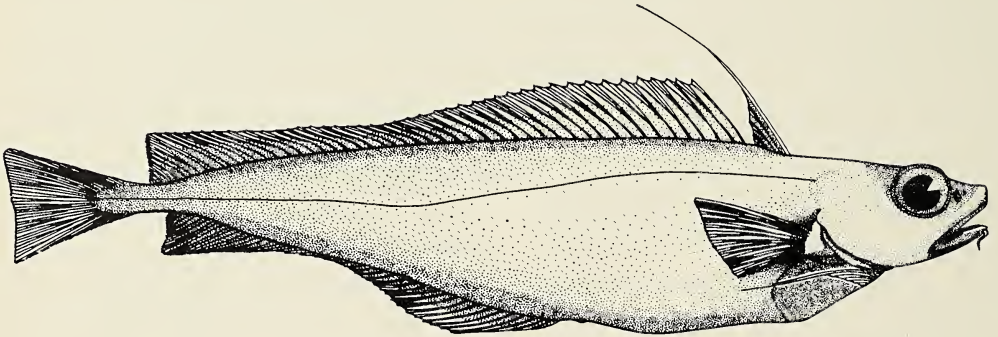


FIG. 2. *Lepidion microcephalus*, sp. nov. Drawing to show details of structure.

its longest rays in the anterior quarter and in the posterior portion in the region of the 35th ray; median rays considerably shorter producing a pronounced indentation in that portion of the fin. Caudal fin of 42 rays, subtruncate, barely emarginate. Lateral line originating at back of head above posterior edge of operculum and descending posteriorly to a point above the anterior 0.33 of the anal fin from which point it runs parallel with the main axis to the end of the caudal peduncle. Thirteen or 14 scales between the first dorsal fin and lateral line; 180 oblique rows of scales in the lateral line. Scales small, cycloid, covering head and origins of all fins. Colour on capture, mottled pinkish brown on grey with black edges to the second dorsal and anal

fins. Radial formula: D.5/54; A.46; P.21; V.7; C.42.

#### DISCUSSION

In this specimen the head length is relatively less than that of all other described members of the genus. The eye diameter is relatively greater than that of all others but *L. eques* (Günther) and *L. lepidion* (Risso) with which it closely corresponds. The depth of body is relatively greater than that of *L. inosimae* (Günther) and less than that of all others with the exception of *L. natalensis* Gilchrist and *L. schmidtii* Svetovidov with which it agrees. The length of snout is relatively less than that of all others but *L. eques*, *L. natalensis*, and *L. ensiferus* (Günther). The

relative distance between the root of the ventral fins and anus, when expressed as a fraction of the head length, is considerably greater than that of all other described members of the genus. The number of scales in the lateral line is greater than that of *L. natalensis*, *L. lepidion*, and *L. modestus* (Franz), fewer than that of *L. guentheri* (Giglioli), *L. oidema* (Tanaka), and *L. capensis* Gilchrist, but equal to that of *L. eques*. The number of scales in the distance between the first dorsal fin and lateral line is fewer than that of all other members of the genus but *L. lepidion*, with which it agrees. The radial formula is different from that of all others described.

This Australian specimen cannot be identified from the key contained in a synopsis of the genus (Norman, 1935), though its close affinity to the group containing *L. lepidion* and *L. eques* is indicated. It is excluded from this group, however, by the relative depth of the caudal peduncle, and from the contained species by the radial formula, relative length of head, relative length of filamentous rays of ventrals and first dorsal, shape of caudal, and by scale counts along the lateral line and between first dorsal fin and lateral line.

From the foregoing then it would seem that, although the Australian specimen has affinities with most other members of the genus, and more particularly with *L. eques* and *L. lepidion*, the differences, in radial formula, body proportions such as relative head length and eye diameter, together with scale counts, are real and therefore separate it from all other members of the genus.

#### *Holotype*

Taken 12 miles east of Schouten Island, Tasmania, from 400–420 fathoms and deposited in the Tasmanian Museum. Registered No. 13225/D160. Total length, 451 mm.

#### ACKNOWLEDGMENT

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## A New Subfamily of Urostylidae from Borneo (Hemiptera: Heteroptera)

W. E. CHINA and JAMES A. SLATER<sup>1</sup>

THROUGH THE KINDNESS of Dr. R. I. Sailer of the United States National Museum we recently have had the opportunity to study a very remarkable insect from Borneo. With some hesitation we place this insect in the pentatomoid family Urostylidae as a new subfamily, although the differences between this new species and previously known urostylids are of considerable magnitude.

The systematic position of this curious insect is of considerable interest. The presence of ventral abdominal trichobothria places *Saileriola* in the Trichophora of Tullgren (1918). Although trichobothria are absent in some Pentatomorpha (Leston, Pendergrast and Southwood, 1954) such as the lygaeid genus *Oxycarenus* and the plataspid *Lestonia*, so far as is known no cimicomorphs possess trichobothria. Likewise the presence of arolia and pseudoarolia precludes many cimicoid groups. Once the position of the species in the trichophora is established, one is faced primarily with the problem of pentatomoid or lygaeoid affinities. The apparently five-segmented antenna is of course pentatomoid, although certainly not definitive; some pentatomoids possess four- and even three-segmented antennae, and five-segmented anten-

nae are known to occur in such dissimilar families as the Hebridae and Nabidae. So far as we know, however, five-segmented antennae are unknown in the Lygaeidae whereas they do represent the predominant condition in the Pentatomoidea. The lack of a claval commissure (Fig. 1a) is rather characteristic of Pentatomoidea, whereas the condition occurs only rarely in the Lygaeidae (i.e. *Geocoris* and *Chauliops*). The partial fusion of the ventral abdominal segments (Fig. 1b) is reminiscent of some Lygaeidae (many Rhyparochrominae, Pamphantinae, *Artemidorus*, etc.), but similar fusion occurs in the Pentatomoidea (*Lestonia*, for example). The peltoid head shape and widely separated coxae are typical pentatomoid characters. In Lygaeidae the coxae are usually closely approximated, although widely separated at times as in some Blissinae such as *Bochrus*. The aedeagus in *Saileriola* closely resembles the pentatomoids rather than the Lygaeidae. The vesica is short with definite conjunctival appendages. The long fine spiral vesica found in the majority of Lygaeidae (but not in the Pachygronthinae and Heterogastrinae) is definitely lacking. The venation of the hind wing (Fig. 2e) is unlike either group, having obviously undergone extreme reduction with the loss of the hamus, distal portion of the cubitus, intervannals, vannals, and jugal veins (terminology follows Leston, 1953).

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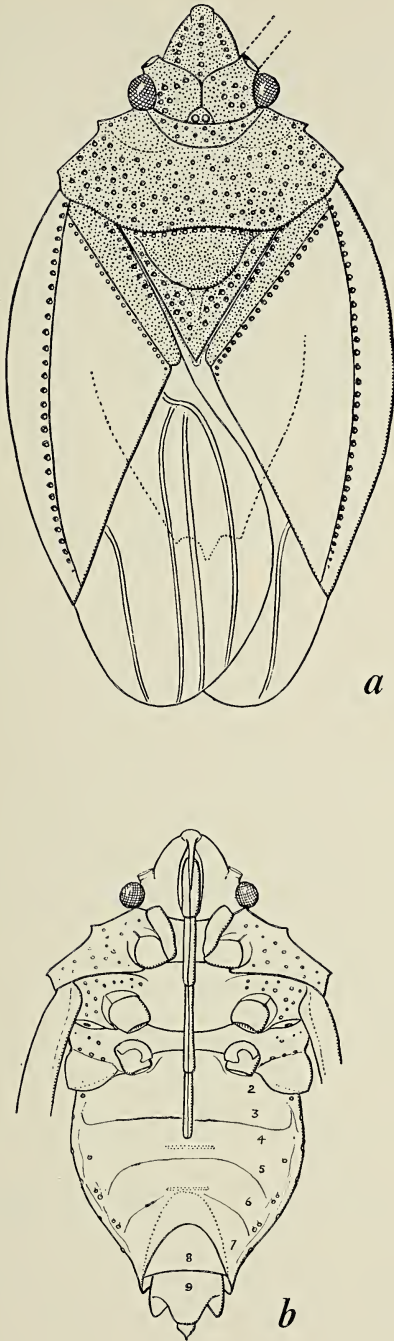


FIG. 1. *Saileriola sandakanensis* n. sp.: *a*, Dorsal aspect of body; *b*, ventral aspect of body showing spiracles and trichobothria, dorsal nymphal scent gland scars shown by dotted lines.

It would appear from the rather general characters mentioned above that we are dealing with a rather anomalous pentatomoid. There is some further evidence to support this viewpoint and also to indicate that the affinities of *Saileriola* are with the Pentatomoidea.

In a number of important features *Saileriola* shows relationship to the Urostylidae, in which family we place it for the present. This family must represent the Proto-Trichophora at the base of the Pentatomidae, Coreidae, and Lygaeidae. *Saileriola* resembles the Urostylidae very closely in the structure of the pygophore (Fig. 3*a*) (see Yang, 1938), the elongate eighth segment of the male, the simple legs, the venation of the hemelytral membrane, the regular punctures of the corium and clavus (also true of many Lygaeidae), and, a feature that we consider of great importance, the position and shape of the area of antennal insertion (Fig. 2*a*). This latter feature has often been used to separate the Coreidae from the Pentatomidae and Lygaeidae. In *Saileriola* this area is more or less dorsal, i.e., placed slightly above the middle line of the eye, as in the Coreidae. However, in the primitive pentatomoid family Urostylidae the insertion of the antennae is exactly as it is in *Saileriola* and the wide annulate antenniferous tubercles are identical. In the genus *Urostylis* the ocelli are placed close together as they are in *Saileriola*. The peltoid head, trochalopodous coxae, pseudarolia, and number and position of the nymphal scent gland scars also indicate a urostylid relationship. Furthermore, in some urostylids an obsolete vertex suture is present as in *Saileriola*, although this may represent a neotenic feature rather than be of phylogenetic importance.

*Saileriola* does have important features not found in other urostylids and differs from them mainly by virtue of the structure of the metathoracic scent gland peritreme, number and position of trichobothria, position of the spiracles, venation of the hind wing and some structural aspects, and relative size of the



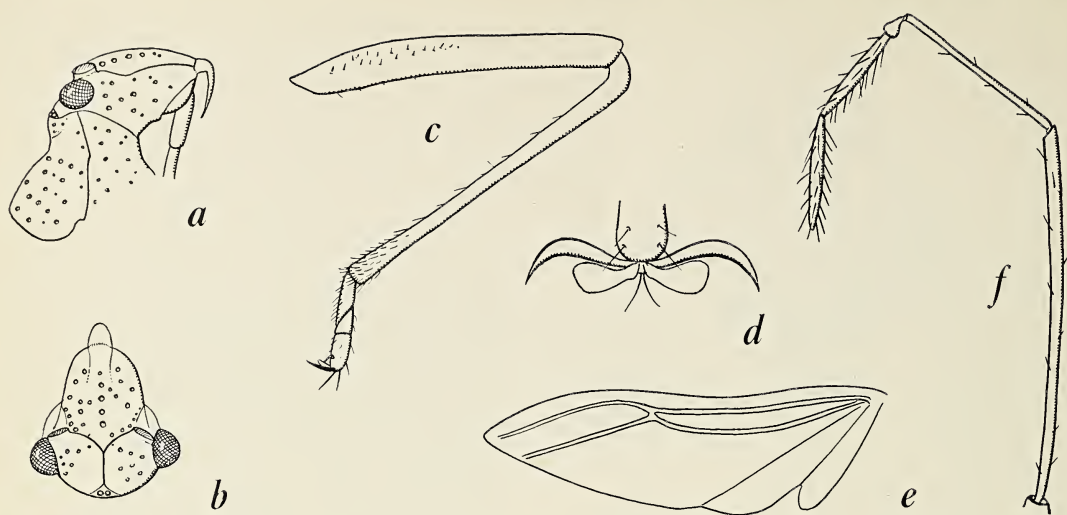


FIG. 2. *Saileriola sandakanensis* n. sp.: *a*, Lateral aspect of head and pronotum; *b*, cephalic aspect of head; *c*, metathoracic leg; *d*, apical portion of tarsus showing claws, arolia, and pseudarolia; *e*, hind wing; *f*, antenna.

pygophore and aedeagus. The extremely small size of the insect is not approached by any of the previously known Urostylidae.

#### SAILERIOLINAE, new subfamily

Vertex sutures present; antennae five segmented, first segment extending considerably beyond apex of head, longer than length of head and pronotum combined, curving slightly outward, third segment very short, subglobular; antenniferous tubercles exerted and visible dorsally; ocelli present and nearly contiguous on mid-line; bucculae short, about one-half length of head; rostrum attaining fourth abdominal sternite; lateral pronotal margins reflexed; spiracles lateral (except ventral on segment two); venation of hind wing reduced to radius, portion of medius and basal portion of cubitus; lateral trichobothria present on fourth, fifth and sixth abdominal segments, the latter two segments with a pair of trichobothria the former with a single one.

Type genus: *Saileriola*, new genus.

#### SAILERIOLA, new genus

Head strongly deflexed, antennae arising laterodorsad, slightly above median lateral

line through eyes, antenniferous tubercles annuliform more or less semicircular; labium four segmented; cuneus and claval commissure absent; meso- and metasternum non-composite; abdomen with six pairs of spiracles; coxae trochalopodous; no prosternal stridulatory sulcus; median trichobothria absent; two linear dorsal scent gland scars present between tergites four and five and five and six; tarsi three segmented, claws apical, pseudoarolia present.

Type species: *Saileriola sandakanensis*, new species.

This new genus will run to *Urostylis* in Yang's (1939) key to the urostylid genera, but is abundantly distinct as discussed above.

#### *Saileriola sandakanensis*, new species

Head, thorax, scutellum, clavus, and coarse punctures on corium adjacent to claval suture and along inner margin of embolium bright mahogany brown; corium and membrane hyaline; body coarsely punctured as follows: head, thorax, scutellum basally and laterally, median basal portion of clavus, a single series on corium along claval suture and a second series running through corium just lateral of

embolium (R + M); entire body nearly glabrous throughout.

Head with clypeus distinctly longer than jugae, vertex with a median suture that becomes bifid and proceeds to lateral margins just anterior to antenniferous tubercles; ocelli nearly contiguous, near base of head on meson, area of head basad of the suture "arms" strongly convex, eyes contiguous with anterolateral pronotal angles, bucculae moderately elevated, labium elongate reaching middle of abdomen, first segment barely attaining base of head, third segment reaching apices of metacoxae, length of head 0.80 mm. (maximum), 0.50 mm. (dorsal view), width across eyes 0.78 mm., interocular space 0.48 mm.; pronotum strongly transverse, anteriorly with broad collar-like area with large, smooth impunctate callus on either side, lateral margins bearing a distinct tooth, small tooth present at humeral angles, margins somewhat flanged and recurved dorsad, posterior margin sinuate, length of pronotum 0.50 mm., maximum pronotal width 1.43 mm.; scutellum large, triangular, reaching apex of clavus, basal half strongly swollen, smooth and shining, laterally and on terminal half flat with a short obscure median carina that does not reach apex, length scutellum 0.62 mm.; meso- and metasterna lacking either a carina or sulcus, metasternal scent gland openings placed at anterior margin of metapleuron, evaporating area simple and

relatively undifferentiated; hemelytra extending far beyond apex of abdomen, corium semihyaline, membrane with four longitudinal veins and no basal cell, the middle two arising from base of inner (cubital) vein, distance from apex of clavus to apex of corium 1.02 mm., distance from apex of corium to apex of membrane 0.50 mm.; hind wing with venation markedly reduced, hamus, antevannal, intervannals, vannals and jugal absent leaving an elongate basal cell formed by R + M anteriorly and Cu posteriorly and a pair of veins, R and M, proceeding distally from the R + M fusion area, vannal fold single; abdominal segments showing marked fusion with distinct sutures visible only between segments three and four, five and six, and six and seven, none of the sutures apparently completely reaching the lateral abdominal margin; no distinct connexival sutures; eighth abdominal segment considerably longer than wide, entirely telescoped into segment seven; pygophore (9th) large, longer than wide with two tooth-like prominences on the relatively small genital atrium, each tooth bearing tuft of mesally directed bristles, small tooth between base of larger tooth and pygophore opening; parameres elongate, slender, linear, with apex slightly clubbed; anal segment (proctiger) semicircular, fringed with short bristles; posterior margin of pygophore above with acute triangular spatulate process; aedeagus typically pentatomoid with median sclerotized paravertical appendage, three pairs of conjunctival appendages and valviform theca; legs simple, mesothoracic and metathoracic coxae very widely separated, coxae very short, trochanters long, hind femora with scattered short, basally tuberculate bristles, tibiae feebly pubescent along under side, more densely so toward apex, first and third tarsal segments longer than segment two, claws widely divergent and narrowly acuminate, pseudoarolia large and flap-like, arolia bristle-like.

HOLOTYPE: Male, Sandakan, Borneo (Baker). No. 63131 in United States National Museum.

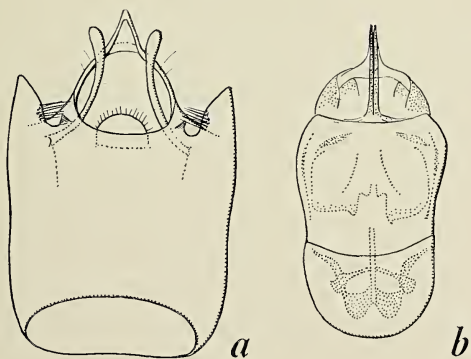


FIG. 3. *Saileriola sandakanensis* n. sp.: a, Ninth segment of abdomen of male, dorsal aspect; b, aedeagus.



## ACKNOWLEDGMENTS

The authors wish to extend their sincere thanks to Dr. R. I. Sailer of the United States National Museum for allowing us to study this interesting species and to Dr. J. C. M. Carvalho of the Museo Nacional Brazil who originally noticed this insect in the collections of the United States National Museum.

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# The General Biology of *Balanus glandula* Darwin

HAROLD BARNES and MARGARET BARNES<sup>1</sup>

THE CIRRIPEDE, *Balanus glandula* Darwin, is a common intertidal barnacle on the Pacific coast of North America, ranging from the Aleutian Islands to the northern border of Mexico. It appears to occupy much the same niche as that of *B. balanoides* (L.) on the eastern side of North America and the coasts of Europe. There has been much work recently on the latter species and it seemed of great interest to compare the general biology and ecology of the two species. A preliminary study is here reported; it has been made possible by the courtesy of Dr. D. B. Quayle of the Provincial Shellfish Laboratory, Ladysmith, Vancouver Island, Canada, and Dr. R. J. Menzies (and later, Dr. K. M. Budge) of the Scripps Institution of Oceanography, La Jolla, California. We wish to thank them for sending regularly samples of preserved material at about monthly intervals over a period of some 18 months.

## THE GENERAL DISTRIBUTION

*B. glandula* has been found in the intertidal zone from the Aleutian Islands (52°N. Lat.) to the northern border of Mexico (32°25'N. Lat.) (Darwin, 1854; Pilsbry, 1916). Such an extensive distribution has been confirmed by Cornwall (1925, 1951, and 1955b). Ricketts and Calvin (1939) state that it is found at Ensenada (32°N. Lat.) and, although they admit that it may occur farther south, this appears to be about the southern limit, for Henry (1941) failed to find it in parts of Lower California and Mexico. Living under widely varying conditions of environment,

this cirripepe is found on wave-swept cliffs (35 miles south of the Mexican border) where all around *Chthamalus* sp. has become the dominant species on the open outer coast and in the quiet bays of enclosed water such as Puget Sound; it may thrive under conditions of poor circulation, low salinity, and slight wave action. At Pacific Grove, while absent from regions of excessively high surf on the open coast (the suggestion has even been made that this is due to the inability of the cyprids to settle under these conditions) it occurs at the uppermost levels of the shore. In more protected areas *B. glandula* is found at a level somewhat below high tide. It is often associated with *Acmaea digitalis* Eschscholtz (= *A. persona*) and *Littorina planaxis* (Nuttall). Although usually occupying a higher level than *Balanus cariosus* (Pallas), when the two are intermingled *B. glandula* may often be found attached to the former rather than to bare rock.

In the Puget Sound area the species appears to thrive best in places which differ markedly from those where it is found on the open coast (Shelford, 1930; Towler, 1930; Worley, 1930; Rice, 1930; Henry, 1940). According to these authors the barnacle is rarely crowded in this region, only a small number of elongated individuals being found; it is most abundant in the salinity range 26–30 parts per thousand and in a zone some three metres above low tide level. Worley (1930) has suggested that temperature is important in regulating the local distribution since the entrance of freshwater into Puget Sound during the summer not only reduces the salinity but also increases the temperature. Conse-

<sup>1</sup> The Marine Station, Millport, Scotland. Manuscript received December 2, 1955.



quently, regions of lower salinity have a higher sea temperature (see also Rice, 1930). In the summer months the surface sea temperature in open water and where wave action is heavy ranges from 9–11°C., whereas in enclosed bays and areas protected from wave action it may reach 11–20°C. during the same period (Shelford and Towler, 1925). The greater temperature during the summer months in enclosed bays may also be responsible for the restriction of *B. glandula*, in such places, to the lower levels of the shore. *B. cariosus* is less resistant to reduced salinity, high temperatures, and products of decomposition than *B. glandula*, so that the latter penetrates farther into the brackish water.

*B. glandula* appears to have a variety of forms depending on its environment, and Pilsbry (1916) takes San Diego as a typical locality and discusses the variety of shapes which occur; conic or convexly conic with small aperture, at San Diego; more cylindrical, much less ribbed (some not at all) and with larger aperture, at San Francisco; a mixture of strongly ribbed, typical individuals and weakly ribbed, cylindrical ones with large aperture in the Puget Sound region. He describes shorter, obliquely conic forms on elongated, columnar individuals from Union Bay, Baynes Sound, British Columbia, and from Sitka both ribbed conic and smooth short, cylindrical forms; his Unalaska specimens were strongly ribbed with wider radii than the California type. Specimens from Atka, although similar to those from Unalaska in the walls, differed from all other types in their opercular valves. Barnacles are extremely plastic as regards their growth form, varying widely according to the conditions of the environment (Barnes and Powell, 1950) and without further work it may be doubted whether these varieties are subspecies or even local races; this has been confirmed by Henry (1942). The individuals used for this present work were similar to those of Pilsbry's typical locality; many examples of the "varieties" were, however, encountered.

Cornwall (1955a) refers to *B. glandula* as small, 10–18 mm. in diameter in uncrowded specimens and height a little more than half the diameter, and suggests that its extremely variable appearance is perhaps due to its wide range of habitat.

In contrast to some other common barnacles of the western coast of America, for example *B. cariosus* and *Chthamalus dalli* Pilsbry, *B. glandula* does not appear to be present in Japanese waters (Hiro, 1935).

#### MATERIAL AND METHODS

The collections were made at about monthly intervals from the shore at Ladysmith, Vancouver Island, and from the pier of the Scripps Institution of Oceanography at La Jolla.

At Ladysmith two series of samples were taken: one, for the examination of the gonads, from the intertidal zone between the 2 and 6 foot levels, was preserved in formalin and a second, which was preserved dry and used for size measurements, from the 5 foot level. At Ladysmith lower high water is + 9 feet and higher high water is 11–13 feet with a tidal range of some 16 feet. The samples from La Jolla were taken from the south side of the pier of Scripps Institution at a point where *B. glandula* forms a zone about 0.4 metre wide. The height of low water is 0.9 feet and the mean tidal range is 3.6 feet (Anon, 1953).

The state of the gonads was examined on about 50 individuals from each sample, the stage of development and colour of the ovaries or egg masses being noted as well as the condition of the male organs. The carino-rostral diameter of up to 150 animals was measured in each sample and an attempt made to separate the year classes by plotting cumulative percentages on arithmetic probability paper. When a new spat fall was well defined and could be clearly followed through several samples it was measured separately. The smaller animals were measured under a binocular microscope with a scaled ocular; for the larger animals calipers were used.

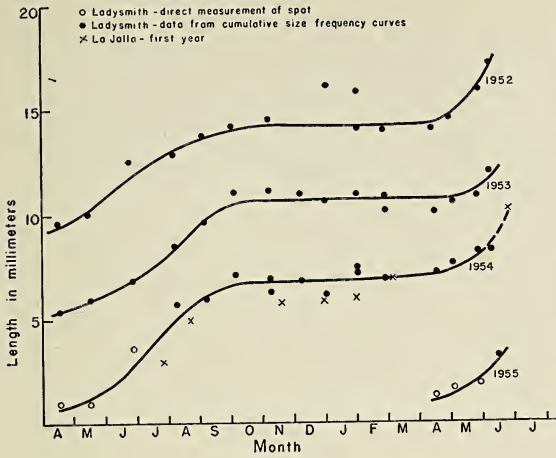


FIG. 1. Growth rate of *Balanus glandula* at Ladysmith, Vancouver Island, and at La Jolla, California.

GROWTH RATE

The cumulative frequency curves showed the presence of several distinct populations in each collection and, although the spread of any year group was considerable, the first three year groups could be separated with reasonable certainty (the subsidiary broods make little impression on the main populations). It is evident that growth takes place largely during the spring and summer months with relatively little or no growth in the winter. This is true both at Ladysmith and La Jolla, although at the latter there is some indication of growth during the winter months particularly of the first season. On the Ladysmith samples it was quite possible to follow directly from the spat fall the first season's growth; from a mean size of 1.2 mm. in April, a size of 7.0 mm. was reached by the end of the summer. At the end of the second season the mean size was some 11.0 mm. and it became 16.0 mm. at the end of the third season. Beyond this point deformities and crowding make the measurement less certain but it would seem that individuals reach a size of about 21 mm.

An examination of Figure 1 suggests that the growth rate at La Jolla is somewhat

slower than at Ladysmith; the mean size of the first year group tends to fall below that value for Ladysmith. Too much significance should not be attached to this possibility since marked individuals were not measured.

On one occasion a sample was available from Ladysmith that had been maintained at a very low tidal level. The growth rate was double that of the animals from the higher regions of the tidal zone, doubtless as a result of the greater periods of immersion at the lower levels (see Barnes and Powell, 1953).

BREEDING

The conditions of the ovaries or egg masses throughout the year are shown in Tables 1 (Ladysmith) and 3 (La Jolla) which give percentage of individuals at any particular stage of development.

At Ladysmith all the animals contained well-developed unfertilised creamy-yellow ovaries in the midwinter sample of December 8. At the same time the vesiculæ seminales were very prominent and the penes long and turgid. By January 3 some 20 per cent contained fertilised eggs present as firm light-yellow masses in the mantle cavity. On February 1 all individuals contained fertilised eggs, with 60 per cent in possession of eyed nauplii. It is clear that fertilisation probably begins in December and extends into January perhaps being a little less synchronous throughout the population than in some other species (Barnes and Barnes, 1954; Crisp, 1954; and Barnes, in press). As the embryos developed, the gorged appearance of the male organs disappeared, the seminal vesicles shrinking and becoming relatively inconspicuous; the penis became less turgid but there was no sign of gross regression.

By the end of February virtually the whole population contained eyed nauplii and these had been almost completely discharged by mid-April. Release into the plankton of the major brood takes place, therefore, in March. This gives a period of probably 2 months as the nearest estimate that can be made for the



TABLE 1

CONDITION OF THE OVARIES OF SPECIMENS OF *Balanus glandula* TAKEN AT LADYSMITH THROUGHOUT THE YEAR

DATE	PERCENTAGE OF SPECIMENS			
	Eggs unfertilised, not well defined	Eggs unfertilised, well defined, creamy yellow	Eggs fertilised, yellow	Eyed nauplii present, yellowish brown to brown
15/ 4/54.....	51	11	27	11
15/ 5/54.....	42	43		15
2/ 6/54.....	50	50		
30/ 6/54.....	← 100 →			
10/ 8/54.....	26	68	4	2
7/ 9/54.....	15	75	5	5
6/10/54.....	← 100 →			
10/11/54.....	20	80		
8/12/54.....		100		
3/ 1/55.....		80	20	
1/ 2/55.....			40	60
27/ 2/55.....			4	96
15/ 4/55.....	71	22		7
5/ 5/55.....	30	55	10	5
7/ 6/55.....	50	50		

period of incubation in the mantle cavity. However, some liberation of nauplii must take place later since eyed nauplii were found up to late May, but this is in only a small fraction of the population. Redevelopment of the ovary takes place, in part, almost as soon as the major brood is released and it is quite evident that small broods are produced later in the year, for a small proportion of specimens were found with eyed nauplii as late as August and September.

Table 2 gives notes supplied by Dr. Quayle on the appearance of the shore settlement of *B. glandula* based on observations made during the course of his own work. These, taken in conjunction with the estimated dates of release given above indicate a planktonic life of about 1 month; they also confirm that the major settlement takes place in the spring with some sporadic liberation into the early summer. His records of the presence of nauplii in the plankton on August 27 as well as September 20 in 1951 also confirm the production of a small autumn brood.

These results also accord with the observations of Johnson (1932) at Friday Harbor, somewhat to the south of Ladysmith; he

found barnacle larvae (species not stated) to first appear in the plankton in February with the maximum number in March and April. In a later paper with R. C. Miller (1935) he also refers to an autumn outburst of *B. glandula*.

The data in Table 3 indicate that at La Jolla the major portion of the sample was full of ripe unfertilised eggs by the end of September and early October. Fertilising began either in October or the early part of November and was complete by December; by the end of this month the greater proportion of the sample contained eyed nauplii, the large majority of which must have been released by the end of January. It is also evident that redevelopment of the ovaries takes place straight after shedding and that smaller broods are developed in March, April, and May inasmuch as up to 24 per cent of the individuals had eyed nauplii during this period. No breeding takes place after May, the ovaries gradually filling up to be ripe again by the end of September.

SIZE OF EGGS AND EGG PRODUCTION

The size of a number of egg cases with well-developed nauplii were measured. They

had a mean length of 0.22 mm. and a mean width of 0.125 mm. Fully developed eggs released from the ovarian tubules before they were fertilised had a diameter of 0.146 mm.

In order to measure the productivity the number of embryos in the egg masses of ripe

individuals was counted. Figure 2 shows a plot of the number of nauplii against the cube of the length of the adult. There is a linear relation suggesting, as might be expected, that the production is a function of the volume as has been found for other species (Barnes, 1953; Barnes and Barnes, 1954). The slope of the line is different, however, from that for the other species. Apart from any intrinsic differences in productivity the relation between volume and length cubed will vary from species to species.

DISCUSSION

Temperature data (means for several years) for La Jolla (kindly supplied by the Scripps Institution) and for protected areas in the neighbourhood of Ladysmith (see Hollister, 1954) together with values at Ladysmith for 1954, are given in Table 4.

At La Jolla the major brood of nauplii is fertilised in November, with a mean sea temperature of 16°–17°C., being released in January when the temperature (14°C.) is close to the minimum for the year. Smaller broods are produced up to May but none during the summer and autumn. Breeding only takes place when the temperature is below about

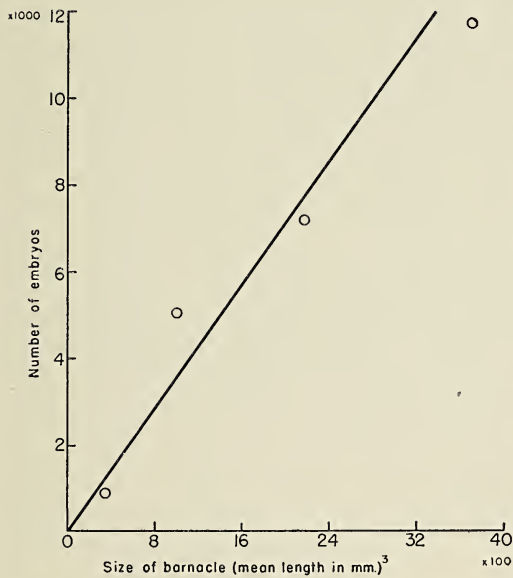


FIG. 2. Relation between number of embryos in the egg masses of ripe *B. glandula* and volume (cube of the length) of the adult.

TABLE 2  
OBSERVATIONS ON THE SETTLEMENT OF *Balanus glandula* AT LADYSMITH

YEAR	MAIN SETTLEMENT AT LADYSMITH	REMARKS
1949.....	April 1	Sooke—May 16; lighter settlement at Ladysmith in July
1950.....	April 19	Intermittent settling until May 20; plankton still contained some nauplii and cyprids on May 22
1951.....		Nauplii in plankton from mid February to mid April; at intervals, May 9–21, July 31, August 27, September 20, none later
1952.....	About March 21	Week later at Ucluelet on west coast of Vancouver Island
1953.....	April 15	Light settlement at Comox (100 miles north of Ladysmith) on April 14
1954.....	April 1–6	Light settlement about June 1
1955.....	April 10, light, April 20, main set, lasting until end of April	At Crofton (8 miles south of Ladysmith) set during first week of May



TABLE 3

CONDITION OF THE OVARIES OF SPECIMENS OF *Balanus glandula* TAKEN AT LA JOLLA THROUGHOUT THE YEAR

DATE	PERCENTAGE OF SPECIMENS			
	Eggs unfertilised, not well defined	Eggs unfertilised, well defined, creamy yellow	Eggs fertilised, yellow	Eyed nauplii present yellowish brown to brown
20/ 7/54.....	24	76		
23/ 8/54.....	8	92		
23/ 9/54.....	15	85		
22/11/54.....		61	24	15
29/12/54.....			17	83
31/ 1/55.....		45	45	10
3/ 3/55.....		40	36	24
20/ 5/55.....		79		21
25/ 6/55.....	33	67		

TABLE 4

TEMPERATURE DATA FOR LA JOLLA AND LADYSMITH

	LA JOLLA (mean of 27 years)	LADYSMITH REGION 1952	LADYSMITH, 3 FEET BELOW SURFACE AND 50 YARDS FROM SAMPLING POSITION, 1954
January.....	14.0	6.2	4.7
February.....	13.9	6.1	5.9
March.....	14.5	6.7	7.0
April.....	15.5	8.2	8.7
May.....	17.2	10.9	13.0
June.....	18.6	13.1	14.7
July.....	19.8	15.4	18.2
August.....	20.6	15.1	18.1
September.....	19.2	13.4	14.5
October.....	18.0	12.1	11.4
November.....	16.3	8.8	9.2
December.....	15.1	7.7	7.1
Average.....	16.9	10.3	11.0
Maximum.....	20.6	15.4	18.2
Minimum.....	13.9	6.1	4.7
Range.....	6.7	9.3	13.5

17°C. At Ladysmith the major brood is fertilised and indeed released during the colder parts of the year when sea temperatures are between 6° and 8°C. However, there is an autumn brood, shed in August and September, which may have been fertilised in June and July when the temperature is again about 17°C. Bearing in mind the northward extension of the species the evidence suggests that the southern limit is determined by minimum temperatures of the order of 17°C., a lower temperature being required for breeding.

When the effects of competition with warm water species are taken into account this is in agreement with the fact that, as far as can be ascertained, temperatures at Ensenada, presumably taken offshore (U. S. Navy Hydrographic Office, 1944), are almost uniform throughout the year, never falling below a mean monthly value of about 15°C.

The upper temperature limit for breeding which takes place in the coldest months of the year is in agreement with a wide distribution northwards. However, if as suggested the

temperature barrier is at 16°–17°C., temperature conditions do not limit the breeding to the colder months of the year at Ladysmith and regions farther to the north; the breeding rhythm is tied to some other factors.

In *B. balanoides*, a boreo-arctic species, breeding appears to be determined by a temperature barrier at about 8°C. so that the southern limit is determined by the southern limit of the mean winter isotherm of 8°C. (Hutchins, 1947). It is found, therefore, farther south on the eastern seaboard of North America than on the coast of Europe as a result of the cold currents coming down the former coast. *B. glandula*, if a boreo-arctic species, seems to have raised the temperature barrier much higher so that it extends farther to the south on the western coast of America. It is of interest to note, however, the resemblance to *B. crenatus* which even near the southern limits of its distribution produces a second brood in the autumn of the year although it is considered to be an arctic species—more so than *B. balanoides*.

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# Observations on Two Species of *Liagora* (Rhodophyta)<sup>1</sup>

T. V. DESIKACHARY<sup>2</sup>

ALTHOUGH THE ONTOGENY of the cystocarp has been studied in a number of species of the nemalionalean genus *Liagora* (Butters, 1911; Børgesen, 1915–20, 1927; Kylin, 1930; Yamada, 1938; Levring, 1941; Abbott, 1945), gaps still exist in our knowledge of the development of this structure. Thus, little precise information is at hand concerning the place of origin of the so-called involucrel filaments and as regards the presence or absence of a fusion-cell in the mature cystocarp of certain species (see Papenfuss, 1946: 433, 434). The present account is based upon a study of two Hawaiian species, *L. maxima* Butters and *L. Papenfussii* Abbott, material of which was kindly placed at the disposal of the writer by Professor Papenfuss.

## LIAGORA MAXIMA

Described by Butters (1911) from the Hawaiian Islands, this species was again reported by Abbott (1945). The material studied by the writer was collected by Papenfuss on the Island of Oahu (1.8 miles west of Nanakuli) on May 16, 1941.

**STRUCTURE OF THALLUS:** The general habit and structure of *Liagora maxima* have been well described by both Butters and Abbott. Although the thallus varies greatly in length, some specimens may attain a height of as much as 40 cm., which marks this species as one of the largest in the genus. The plants are very much calcified. The main branches arise at or near the base and constitute per-

current axes from which issue branches of limited growth. The main axes and their branches are composed of a central core of compact, vertical filaments (the medulla) from which are produced radially directed assimilatory laterals (the cortex). The lateral filaments are repeatedly dichotomously branched—up to the sixth order (Fig. 1*a*). The length of the cells of these filaments and the distance between the dichotomies gradually diminish toward the surface of the thallus. In younger parts the assimilatory filaments often terminate in long hairs.

**REPRODUCTION:** *Liagora maxima* is dioecious. The spermatangia are borne in clusters at the extremities of the assimilatory filaments (Fig. 1*b*, *e*, *f*). At the tips of these filaments from one to six spermatangial mother cells are formed, each of which produces one to three spermatangia.

The carpogonial branches are produced laterally on the assimilatory filaments (Figs. 1*c*, *d*, *g*, 2*d*) and usually in the younger parts of the thallus—at times even before the assimilatory filaments are fully developed (Fig. 1*d*, *g*). They are generally formed on the cells behind the third or fourth furcation and are characteristically composed of three cells (Figs. 1*d*, 2*a*, *b*, *d*, *b*) but are sometimes four-celled. The mature carpogonium has a long trichogyne which projects beyond the periphery of the thallus. In a few instances spermatia were seen attached to the tip of the trichogyne (Fig. 2*d*).

After fertilization the content of the trichogyne is separated from that of the carpogonium proper (Fig. 2*a*, *b*, *b*). The carpogonium then divides by a transverse septum, forming a stalk cell and a gonimoblast initial (Figs. 2*e*, 3*e*) from which is produced the gonimoblast (Fig. 2*c*). The gonimoblast con-

<sup>1</sup> This study was carried out during the tenure of a Fulbright award, for which the writer is very grateful. Thanks are due Professor George F. Papenfuss of the University of California, Berkeley, for his kind guidance during the investigation. Manuscript received November 22, 1955.

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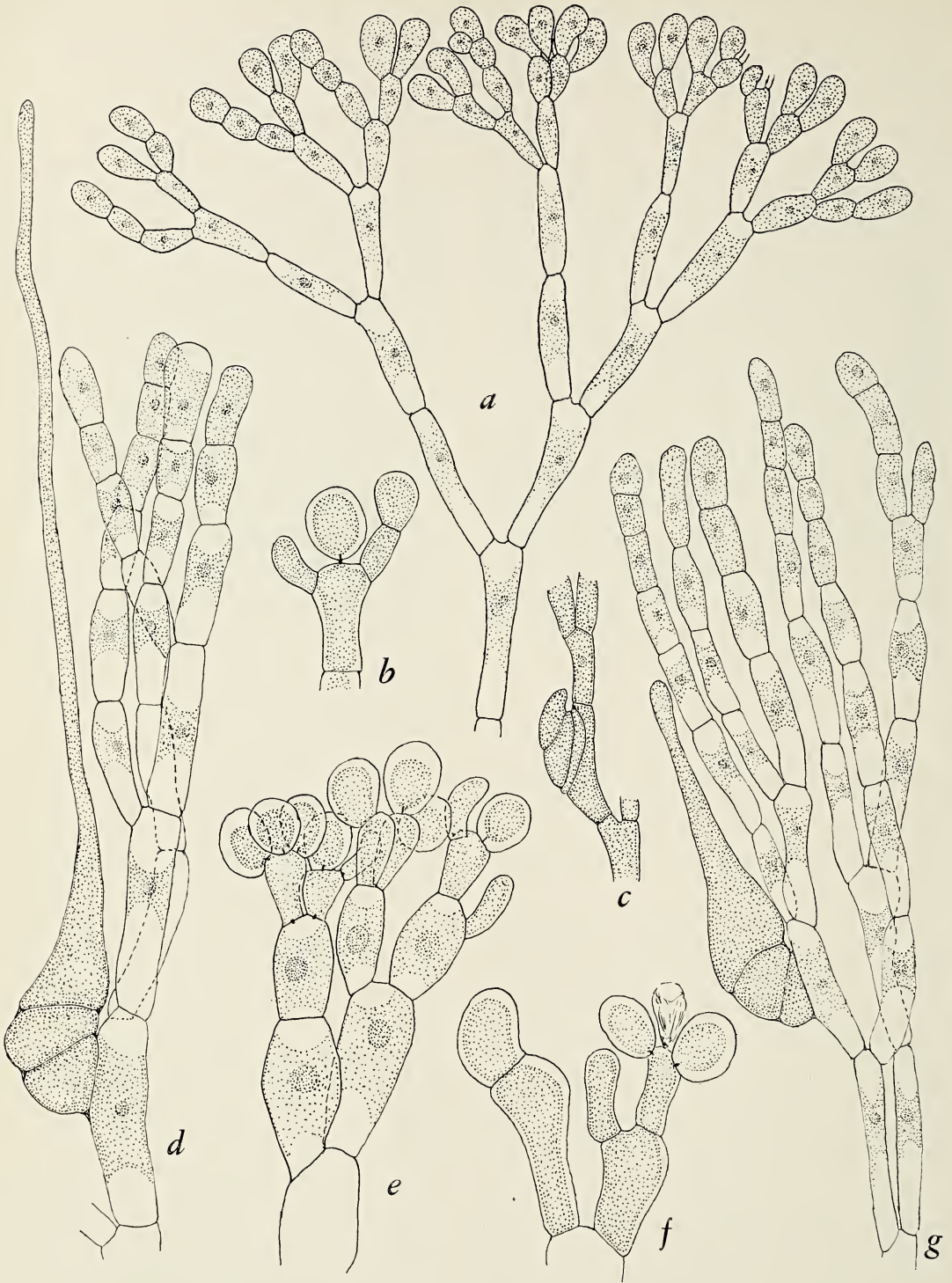


FIG. 1. *Liagora maxima* Butters. *a*, Assimilatory filament,  $\times 553$ ; *b*, *e*, *f*, antheridia,  $\times 2266$ ; *c*, *d*, *g*, carpogonial branches,  $\times 1133$ .

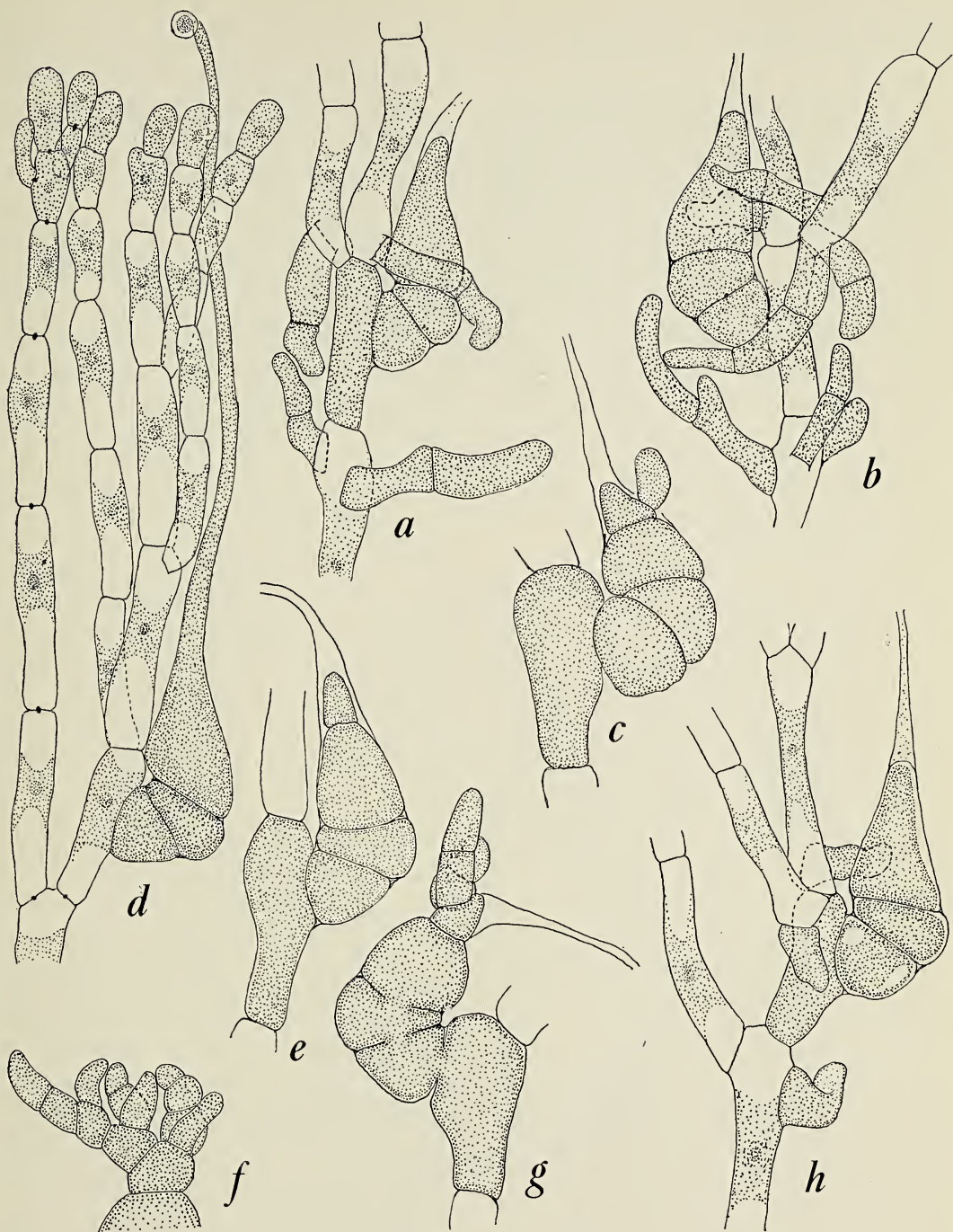


FIG. 2. *Liagora maxima* Butters. *a-c, e-h*, Post fertilization stages; *d*, carpogonial branch showing trichogyne with attached spermatium. All  $\times 1020$ .



sists of branched filaments (Figs. 2*f*, *g*, 3*a-c*) which form terminal carposporangia (Fig. 3*c*, *d*).

Soon after fertilization of the carpogonium, involuclal filaments are initiated. These filaments are formed by the vegetative cells above and below the supporting cell and rarely also by other vegetative cells in the neighborhood of the carpogonial branch (Fig. 2*a*, *b*, *b*). The involuclal filaments grow up and around the developing gonimoblast and are very much branched (Fig. 3*a*). They are generally narrower than the gonimoblast filaments and have a dense cytoplasmic content. Later, as the development of the gonimoblast advances, vacuolization of the cells of the involuclal filaments becomes evident and the filaments ultimately lose most of their contents and become colorless (Fig. 3*c*).

Concurrently with the formation of the gonimoblast, changes occur in the cells of the carpogonial branch. These cells acquire a dense content and increase in size, often becoming two or three times larger than they originally were (Fig. 2*c*, *g*). The protoplasmic connections between the cells gradually widen, resulting finally in the establishment of a large fusion-cell, comprised of the supporting cell, the cells of the carpogonial branch, and the stalk cell (Figs. 2*g*, 3*b*, *f*). The gonimoblast initial is not incorporated in the fusion-cell. At first, the fusion-cell has a dense content but later, as the gonimoblast continues growth, the content gradually becomes vacuolated and less dense.

The account of the development of the gonimoblast of *Liagora maxima* presented here is, in some respects, at variance with the description as given by Abbott (1945). According to her the carpogonial branch is four-celled when mature. In the present investigation, the mature carpogonial branches were almost always observed to be three-celled—only rarely do they become four-celled. This is the only species of *Liagora*, in addition to *L. viscida* (Kylin, 1930), in which a fusion-cell has been observed. According to Abbott the

involuclal filaments are formed from the supporting cell, but in the present study they were observed to be produced by the vegetative cells above and below the supporting cell—never from the supporting cell.

#### LIAGORA PAPENFUSSII

This species was described by Abbott (1945) from material collected by Papenfuss on the Island of Oahu. The writer's observations are based on part of the same material. *Liagora Papenfussii* is the fourth of the known species of *Liagora* in which the gonimoblast has been observed to produce tetrasporangia instead of carposporangia (i.e., monosporangia). The other three species are *L. tetrasporifera* Børgesen (1927), Japanese specimens of *L. pinnata* Harvey (Yamada, 1938), and *L. brachyclada* Decaisne (Levring, 1941). Børgesen (1927) and Kylin (1930) have made detailed studies of *L. tetrasporifera*. In its development this species differs in some respects from *L. viscida* as observed by Kylin (1930). A short account of the main features of *L. Papenfussii* follows. The author's observations on this species agree entirely with those of Abbott and point to the distinctness of the species.

**STRUCTURE OF THALLUS:** The thallus is composed of a core of large axial filaments from which issue radially directed assimilatory filaments. These lateral filaments are divided four to six times, the distance between the branches being quite short (Fig. 4*a*, *b*). The cells are short and barrel-shaped toward the axial part of the thallus and decrease in length toward the periphery. They have a thick wall and are joined by conspicuous cytoplasmic connections. In the younger parts of the thallus the assimilatory filaments often terminate in short hairs.

**REPRODUCTION:** *Liagora Papenfussii* is monoecious. The spermatangia are produced in clusters at the tips of the assimilatory filaments. From the terminal cell of an assimilatory filament two to three spermatangial mother cells are generally cut off, each of

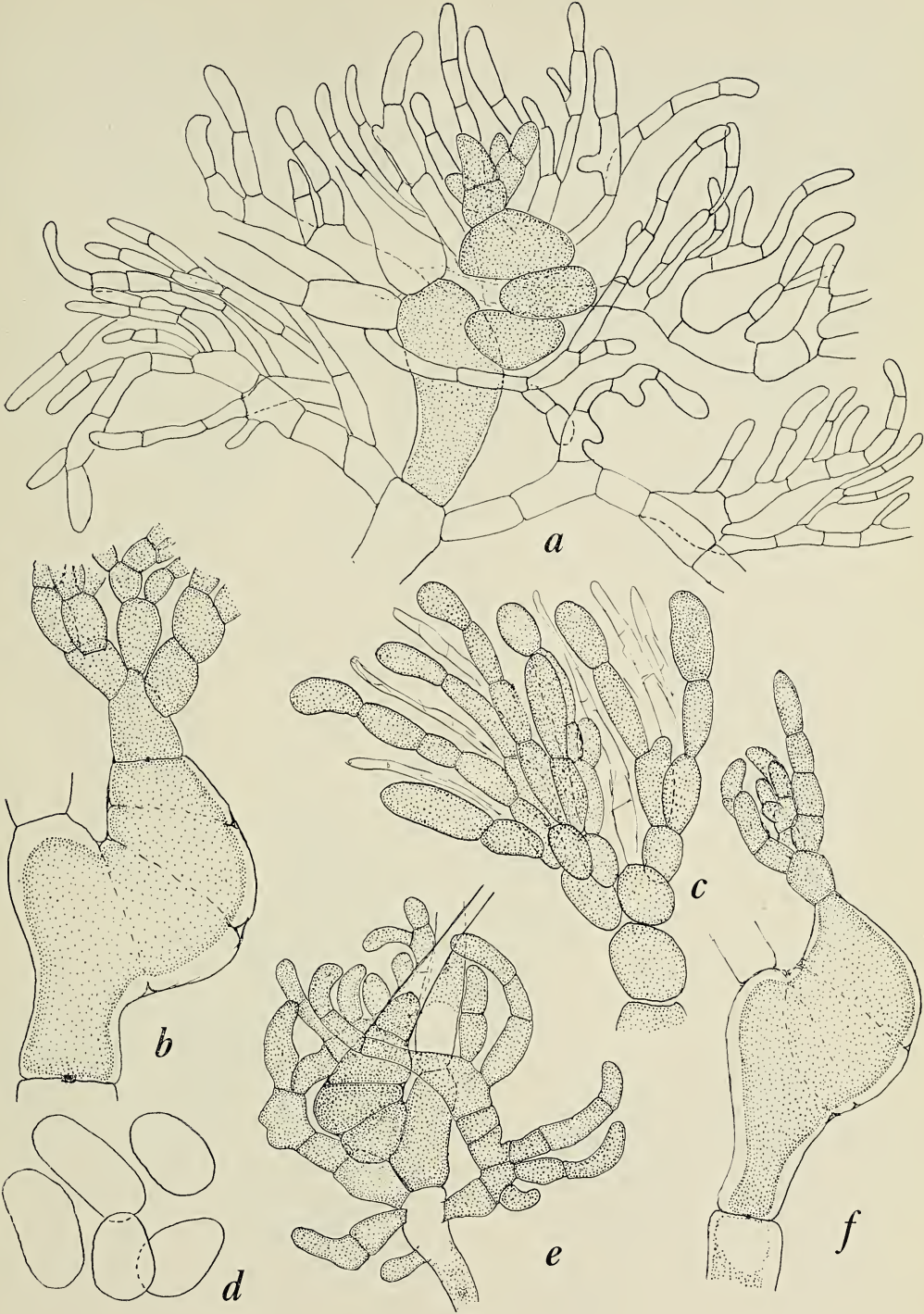


FIG. 3. *Liagora maxima* Butters. a-c, e, f, Post fertilization stages; d, carpospores. a, X605; b-f, X935.



which gives rise to two or three spermatangia (Fig. 4*a, b*).

The carpogonial branches are produced as lateral accessory branches on the assimilatory filaments and usually behind the third or fourth furcation of these filaments. The carpogonial branch initial is cut off as a lens-

shaped cell (Fig. 4*e*). By repeated division it gives rise to a four-celled branch, the terminal cell of which is the carpogonium (Fig. 4*c, d, f, g*). In the mature condition the carpogonium has a long trichogyne which extends to the surface of the thallus (Fig. 5*a*).

After fertilization the cytoplasm of the

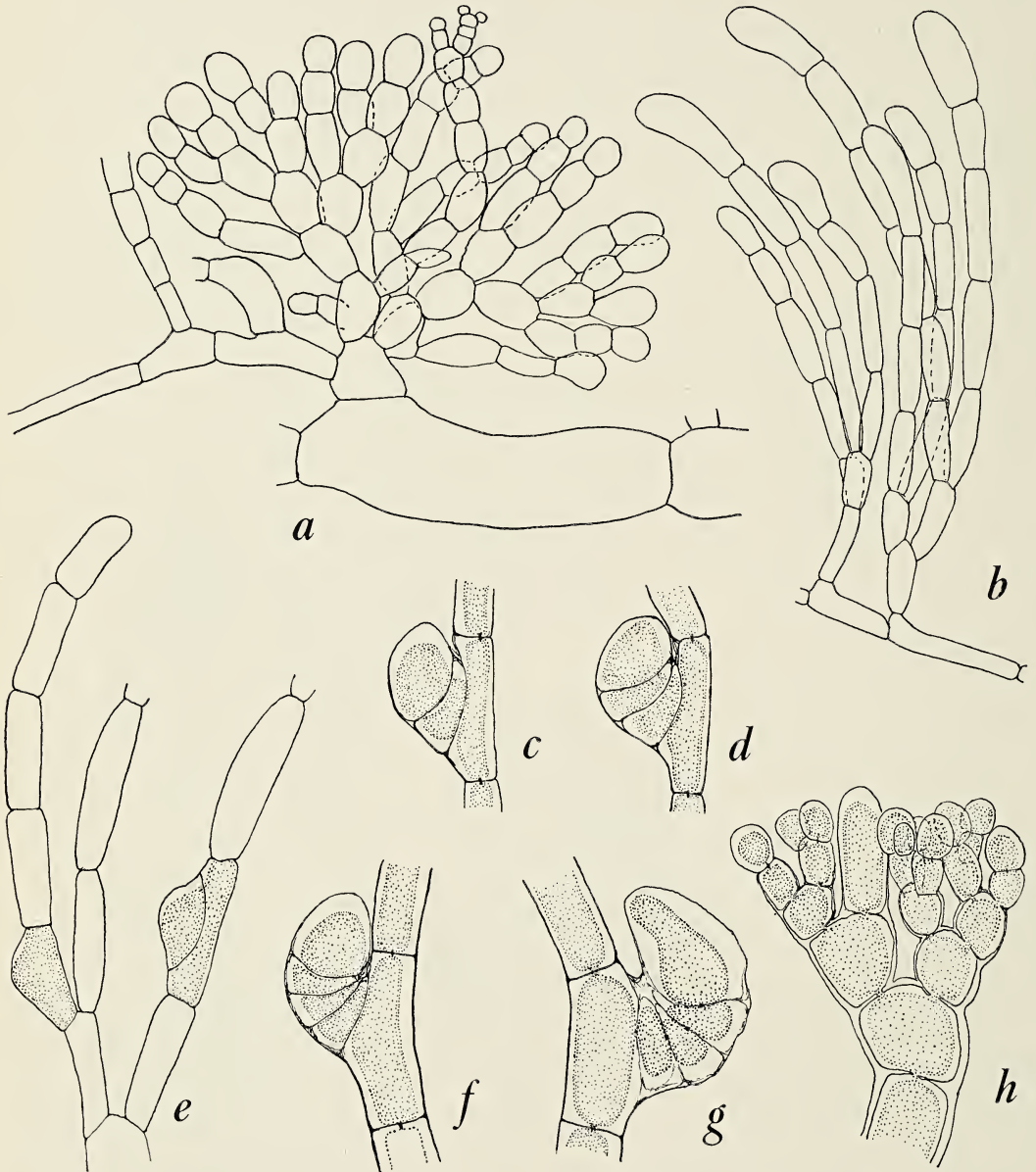


FIG. 4. *Liagora Papenfussii* Abbott. *a, b*, Old and young assimilatory branches, respectively; *c-g*, development of carpogonial branches; *h*, antheridia. *a*,  $\times 270$ ; *b*,  $\times 660$ ; *c-h*,  $\times 1020$ .

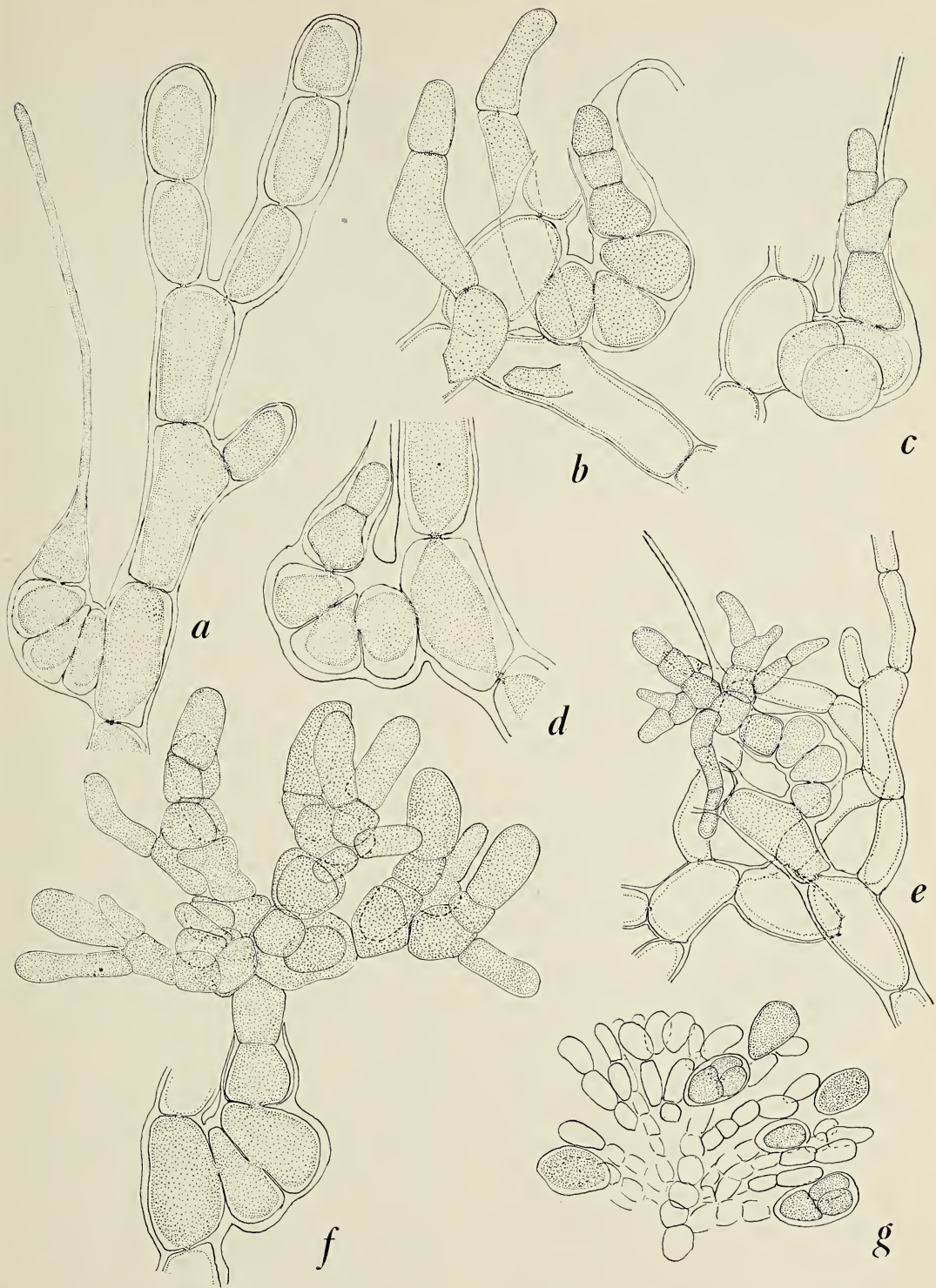


FIG. 5. *Liagora Papenfussii* Abbott. a-f, Post fertilization stages; g, old cystocarp showing tetrasporangia. a-d, f,  $\times 765$ ; e,  $\times 495$ ; g,  $\times 373$ .



trichogyne is separated from that of the carpogonium proper and the carpogonium then divides by a transverse wall (Fig. 5*d*) into a stalk cell and the gonimoblast initial. The gonimoblast initial gives rise to a much-branched gonimoblast (Fig. 5*b*, *c*, *e*, *f*). The gonimoblast filaments form terminal tetrasporangia (Fig. 5*g*).

A fusion-cell is apparently not formed in this species. At times, however, a distinct enlargement of the cytoplasmic connections occurs (Fig. 5*d*, *f*).

Only a slight development of involucrial filaments occurs (Fig. 5*b*, *e*). A few filaments are formed from the vegetative cells above the supporting cell and occasionally from cells of the other vegetative filaments near the supporting cell.

#### DISCUSSION AND SUMMARY

The observations on *Liagora maxima* and *L. Papenfussii* have contributed to an elucidation of two points, in particular, in the development of the cystocarp in *Liagora*.

Previously the occurrence of a fusion-cell in the cystocarp of *Liagora* has been reported only in *L. viscida* (Kylin, 1930). The observation of such a cell in *L. maxima* shows that this is a condition which may occur also in some of the other species of *Liagora*. An investigation of the numerous species of this genus with respect to this feature would be of interest.

Involucrial filaments have been reported as present in the cystocarp of a number of species of *Liagora*. In most instances authors have neglected to state from which cells these filaments are derived. It is also not possible to obtain this information from the published illustrations. According to Kylin (1930: 9), involucrial filaments are not produced in *L. viscida*. Hamel (1930: 76), however, states that such filaments are present in this species and that they are formed by the cells of the carpogonial branch. Abbott (1945: 148) described the involucrial filaments as issuing

from the supporting cell in *L. maxima*. The present writer's observations show that in the latter species they are produced by the vegetative cells above and below the supporting cell and rarely also by other vegetative cells in the vicinity of the carpogonial branch. Precise information on the place of origin of these filaments in the various species of *Liagora* in which they occur is highly desirable.

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## Notes on Ecology, Systematics, and Development of Some Mysidacea and Euphausiacea (Crustacea) from New Zealand

BRIAN M. BARY<sup>1</sup>

DURING SURVEYING OPERATIONS of H.M.N. Z.S. "Lachlan" in January, February, and March, 1951, opportunities occurred for making biological and oceanographic collections. Stations were kept in eastern and southern nearshore and oceanic waters between Wellington, New Zealand, and Auckland and Campbell islands, some 400 and more miles south of South Island, New Zealand. A series of specimens was obtained which has furnished information on ecology, development, and morphology of a number of southern cool-water species. This report concerns the Crustacea of the orders Mysidacea and Euphausiacea.

Little information, other than of a systematic nature with brief ecological information, has been available on New Zealand zooplankton. In 1923 Tattersall reported on 12 species of Mysidacea from collections made by H.M.S. "Terra Nova" about New Zealand. Seven of these were new species, 6 from the genus *Tenagomysis*. He listed and discussed a total of 15 species, predominantly from the northern, subtropical waters; Chilton (1926) briefly summarised these data. *Tenagomysis*, with 9 species, was regarded by Tattersall as an endemic and characteristic genus of New Zealand, but since then Ii (1937) and Nouvel (1942) have recorded single species from Japan and the Golfe de Gascogne, respectively. Tattersall (1955) adds a further two species, *Boreomysis rostrata* Illig, and *Euchaetomera zurstrasseni* (Illig).

Mysids were absent from the majority of the 86 stations kept from "Lachlan." Two

species of *Tenagomysis* were captured, both in the shallow waters (approximately 20 m.) of Foveaux Strait, at the southern extremity of South Island. *T. macropsis* Tattersall was present at 18 and *T. tenuipes* Tattersall at 13 stations. Specimens were abundant at times, and from them it has been possible to provide additional information on the systematic morphology of *T. tenuipes* (described originally from a single male) and to give an account of the larval development of both species.

Tattersall (1924) tabulated 15 species of euphausiids according to their distribution about New Zealand. Eight had been taken by H.M.S. "Challenger" (Sars, 1885) and 7 others were among the 12 species collected by "Terra Nova," all from northern waters. The species belonged predominantly in tropical and subtropical waters.

Five species were present in "Lachlan" collections, namely *Nyctiphanes australis* Sars, *Euphausia lucens* Hansen, *E. vallentini* Stebbing, *Thysanoessa gregaria* Sars, and *Nematoscelis megalops* (?) Sars. *N. megalops* (?) is a new record for the southern Pacific (Boden, 1954), but the others have been recorded previously from New Zealand. The northernmost record of *E. vallentini* was 47° 37'S (171° 47'E) which is in keeping with its more southern range (John, 1936). *E. lucens*, a northern subantarctic species (John, 1936) did not occur south of New Zealand. *Thysanoessa gregaria* occurred sparingly in Cook Strait—between North and South islands—but was present in greater numbers in offshore, subantarctic waters, and it extended southward to Auckland and Campbell islands. *Nyctiphanes australis* occurred only in coastal water.

<sup>1</sup> New Zealand Defence Scientific Corps, % Navy Office, Wellington. Manuscript received August 17, 1955.



Euphausiid developmental stages were captured and these have furnished the larval history of *Euphausia lucens*, a variety of instars of the three furciliars of *Nyctiphanes australis*, and notes on the early furcilia stages of *Thysanoessa gregaria*.

Salinities and temperatures of the waters in which species occurred have been used to confirm the distribution shown by conventional chart plots. Some data on diurnal variation, as indicated through changes with time in numbers taken at the surface, contribute

additional information for both mysids and euphausiids.

#### MATERIAL AND METHODS

Collections were made at 86 stations kept during the surveying routine of the naval frigate, H.M.N.Z.S. "Lachlan." Two series were run between Cook Strait and Dunedin, one in January and the other in March, 1951. The March, but not the January series, crossed the subtropical convergence. The bulk of the stations were situated between Dunedin and

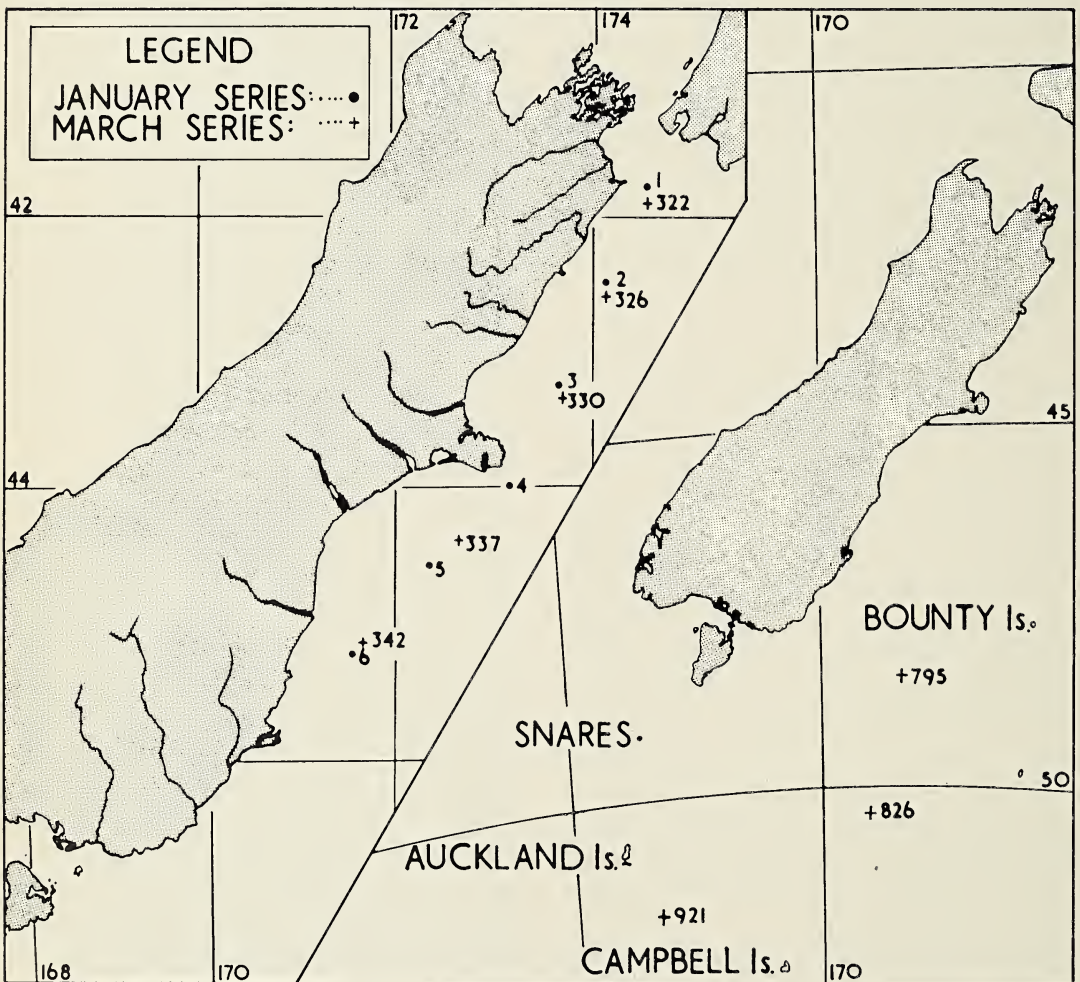


FIG. 1. The plankton stations kept by H.M.N.Z.S. "Lachlan" during January, March, and November, 1951. Left—the January (1-6) and March stations between Cook Strait and Dunedin. Right—the November stations between southern New Zealand and the Auckland-Campbell islands area.

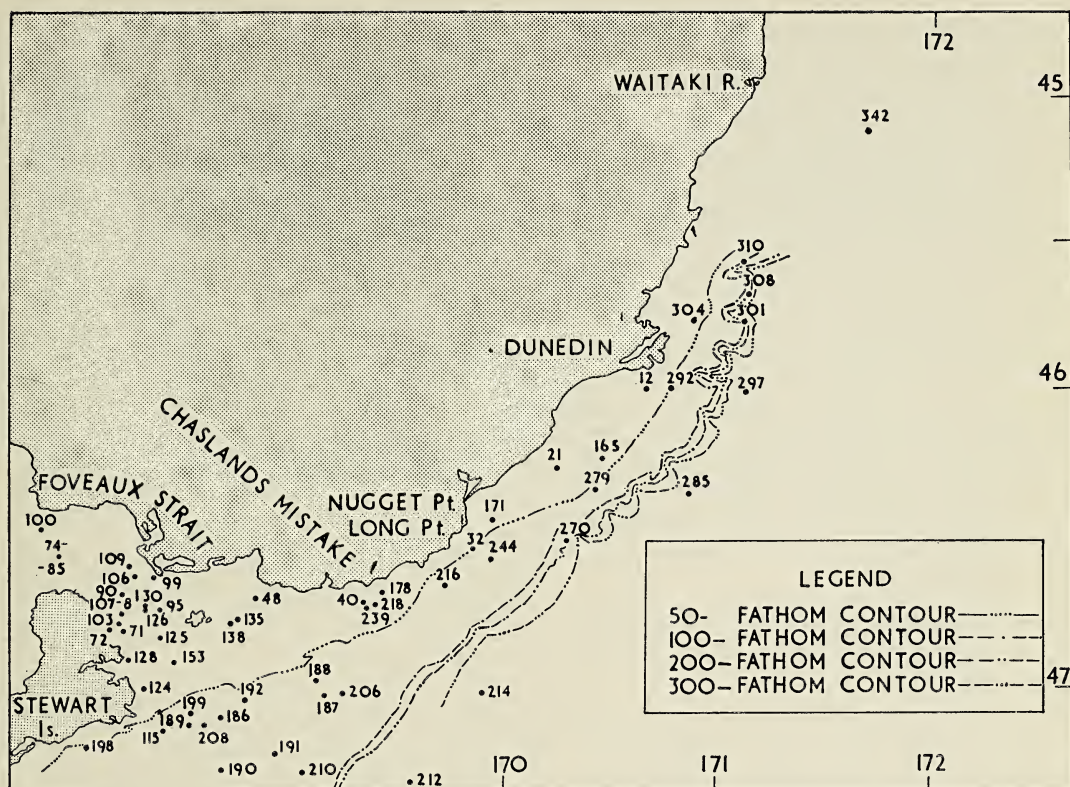


FIG. 2. The plankton stations kept by H.M.N.Z.S. "Lachlan" in and about Foveaux Strait at the southern end of New Zealand during January, February, and March, 1951.

western Foveaux Strait and were kept during January, February, and March 1951. Three were included from a series run between southern New Zealand and the Auckland-Campbell islands area in November 1951. Plankton stations are shown in Figures 1 and 2.

Day and night stations were kept as opportunity permitted. Because the ship's surveying routine could not be interrupted for lengthy tows these were restricted to 3 minutes except at stations 74 to 85 where the net was streamed for 15 minutes (see later). Most were surface hauls, supplemented on occasion with oblique tows from 75 metres to the surface when in deep waters, e.g., on passage from Wellington to Dunedin. As the ship was usually in a particular area for some time, the inadequacy of the 3-minute tow in a position

under certain conditions was largely overcome by making numbers of tows under various conditions of time and weather. The net was 50 centimeters diameter with a 16- to 18-mesh grit gauze in the outer portion, a 29-mesh middle portion and 80-mesh inner portion running to the cup. Care was taken to ensure uniform procedure during sampling: the ship's speed was maintained as nearly as possible at 2 knots, and depth of tows made within the surface 2 metres; the same net structure was used throughout the series, the materials being renewed frequently. Because of this standardisation, samples could be compared and some quantitative data obtained.

Surface temperatures and water samples were taken at each net-station, and usually at several intervening positions as well. Salinity determinations were made at the Dominion Laboratory, Wellington.



OBSERVATIONS ON THE SYSTEMATICS AND  
ECOLOGY OF MYSIDS

## Order MYSIDACEA

## Suborder MYSIDA

## Tribe LEPTOMYSINI

Genus TENAGOMYSIS G. M. Thomson, 1900

**Tenagomysis macropsis** Tattersall

Figs. 3, 4

*Tenagomysis macropsis* Tattersall, 1923.

Males, females, and juveniles (one tow consisting of about 60,000 individuals) were taken in 18 samples which were confined to northern and western Foveaux Strait, southern New Zealand.

Tattersall gives a full diagnosis of this species to which reference should be made for greater detail.

Figure 3 illustrates the external appearance of an adult 8.9 mm. male and the fourth pleopod. Characteristics which aid identification are: the rounded rostral plate with anterolateral, curved spines; the elongate eyestalk; the 3 tarsal joints of the thoracic limbs; the spination and proportional lengths of telson and inner and outer uropods, Figure 4b.

**Tenagomysis tenuipes** Tattersall

Fig. 5

*Tenagomysis tenuipes* Tattersall, 1918, 1923.

Tattersall described this species from a single male, 21 mm. long, taken in Carnley Harbour, Auckland Islands. In the present samples almost 500 specimens of both males and females were taken in 13 hauls from western Foveaux Strait (in the same area as, and often together with, *T. macropsis*) and from eastward of Stewart Island. Numerous juveniles were also captured.

Mature males reached a length of 21.3 mm. and mature females 19.9 mm. Brood-pouch juveniles, ready to be shed, were 4.2 mm. in length. Tattersall's diagnosis is adequate, but

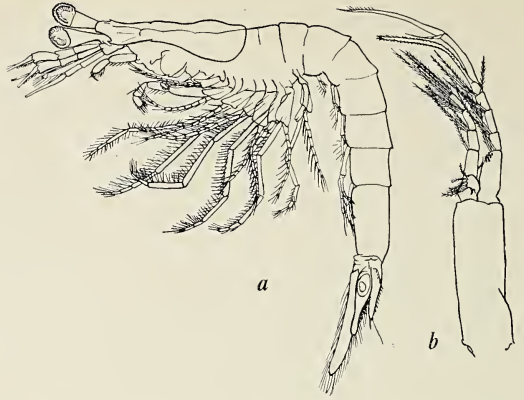


FIG. 3. *Tenagomysis macropsis* Tattersall. a, An 8.9 mm. adult male; b, fourth pleopod.

inasmuch as large numbers of both sexes were examined in the present material, and some additional information obtained, a full description is given.

Both males and females are moderately slender with large black eyes; they are often brown (preserved) with conspicuous chromatophores.

The carapace exposes the last two thoracic segments completely; it is approximately one-third the length of the body, is produced anteriorly into a broadly triangular rostral plate and has rounded anteroventral angles (Fig. 5a).

The peduncle of antenna 1 (Fig. 5a, b) is long and slender in the female, but stouter in the male with a long, densely hirsute male process. Segment 1 is slender, curves outward and dorsad, and is longer than segments 2 and 3 together; segment 2 is approximately one-third as long as segment 3 which has, distally, a stout mediodorsal spine and three or four lateral setae.

In antenna 2, the peduncle of the endopod (Fig. 5a, c) is not as long as segment 1 of antenna 1. There is a stout spine ventrally on segment 1 of the endopod, and segment 2 is longer than segments 1 or 3. The squame is 11 or 12 times as long as wide and extends from one-sixth to one-fourth of its length beyond the peduncle of antenna 1. It pos-

sesses an articulation distally at 0.9 of its length and a stout spine ventrally on its basal segment; a bluntly pointed process extends dorsad between the basal segments of the squame and endopod.

The thoracic appendages are long and slender. Each limb has a multi-jointed tarsus,

the number of joints being 5 on the first two legs, 8 or 9 on the third, 11 to 14 on the fourth to the seventh, and 9 or 10 on the eighth. There is some indication that females may have one or two fewer joints on some legs (see Table 1). Epipodial processes are pronounced, especially on the first leg (Fig.

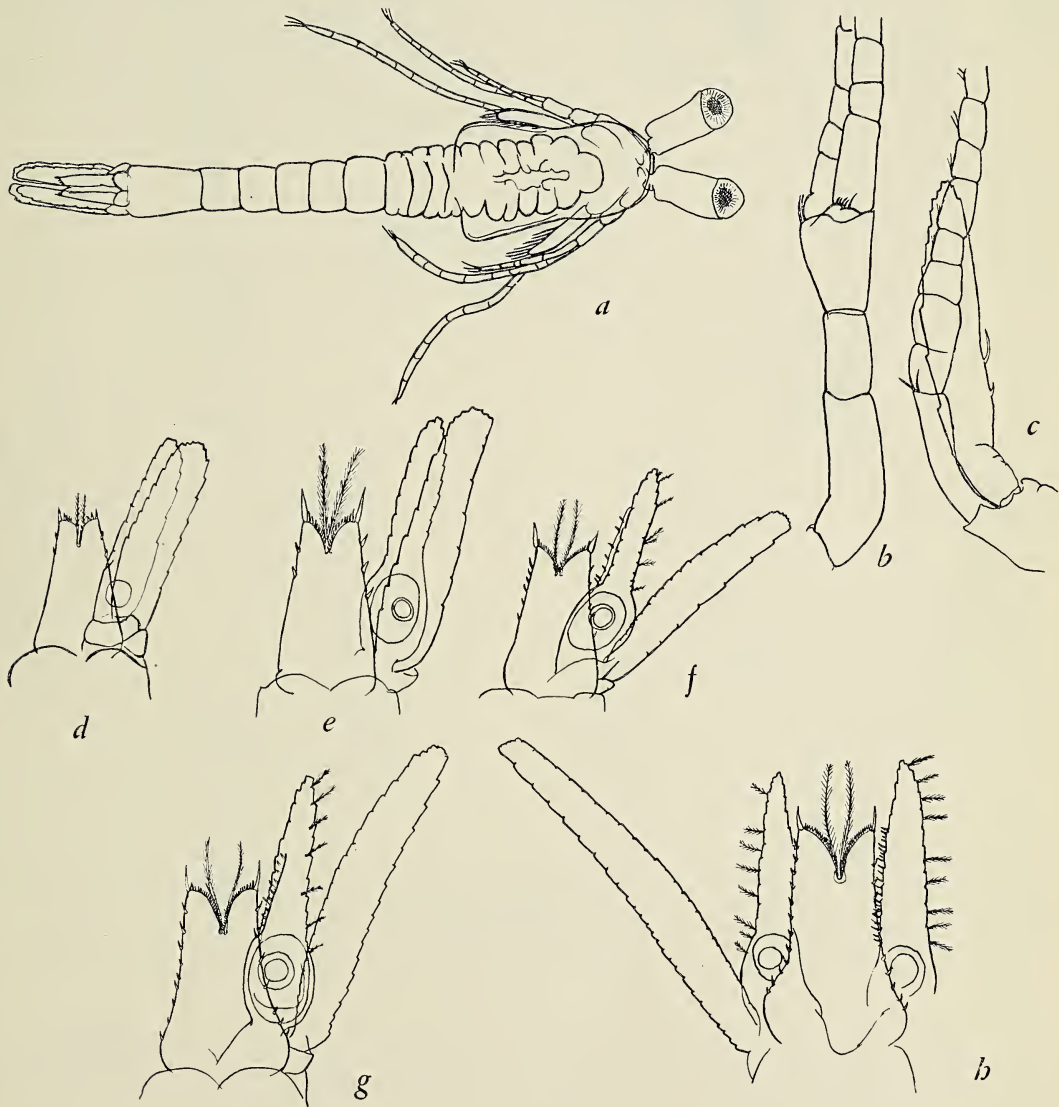


FIG. 4. *Tenagomysis macropsis*. a-g, Developmental stages: a, A 2.2 mm. specimen from the brood pouch, (thoracic limbs not shown); b, antenna 1 of same; c, antenna 2 of same, with squame developing; d, telson and uropods of same; e, telson and uropods of a 2.7 mm. (free living) specimen; f, telson and uropods of a 5.0 mm. specimen; g, telson and uropods of a 7.0 mm. specimen. h, Telson and uropods of adult, 9 mm. male. Magnification of f and g is 0.6 that of d and e.



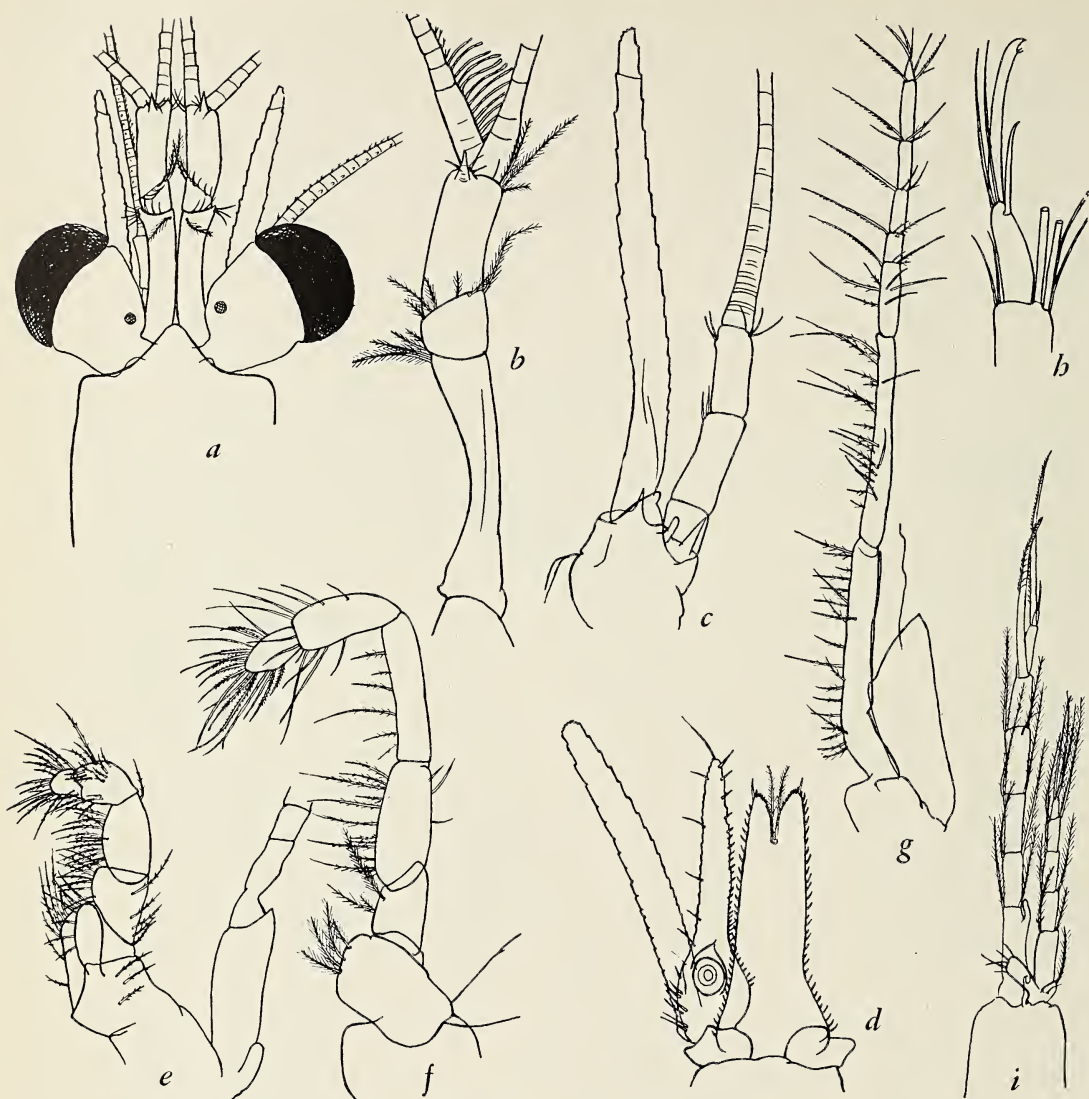


FIG. 5. *Tenagomysis tenuipes* Tattersall. *a-b*, Structure of a 9.8 mm. specimen. *a*, Anterodorsal aspect; *b*, antenna 1, dorsal; *c*, antenna 2, with squame; *d*, telson and uropods; *e*, first thoracic limb; *f*, second thoracic limb; *g*, third thoracic limb; *h*, dactyl of thoracic limb. *i*, The fourth pleopod of a 16.9 mm. male.

5*e, f*), and setose, the number of setae decreasing from leg one to leg eight which has a few only. Exopods are present on all legs; the basal segment is freely acuminate at the outer distal corner and the flagella has 9 segments on all except the first leg on which it has 8.

There are no spines on the abdomen and the sixth somite is twice as long as the fifth and as long as the telson.

The telson (Fig. 5*d* illustrates the telson and uropods of a half-grown specimen) is ventrally keeled and is cleft for one-fifth of its length; the cleft has 50 to 60 pectinations

to each margin and 2 plumose setae at its apex; the lateral margins are provided with about 36 spines and one, longer terminal one. The inner uropod is 1.25 times as long as the telson and carries 85 to 90 spines on its inner margin, often in groups of 2 to 4; for most of the length of the uropod these spines are closely spaced, but the spacing increases distally. On the outer margin are the usual long setae, and an additional series of short ones which are more densely grouped about the position of the statocyst. The outer uropod is 1.5 times as long as the inner, is narrow and more or less parallel-sided.

In pleopod 4 of the male (Fig. 5*i*) the outer ramus is almost twice the length of the inner; the penultimate and antepenultimate segments bear long spines, each with spinules which, on the penultimate spine, occur over almost its whole length and on the antepenultimate spine, over the distal half only. Proximally and medially on the first segment of the outer ramus is a short blunt process which is inclined towards the abdomen; distally on the same side of the same segment is a much longer process pointing away from the abdomen. The first segment of the inner ramus of pleopod 5 bears the usual proximal inner lamella, and there is an additional, smaller one carrying a single seta, at the distal one-third of the same segment.

Table 1 indicates that a general increase in the number of joints in the tarsal segment and some small variation in the number of joints of any one limb may occur. The latter varia-

tions may be apparent in a single specimen, e.g., in leg 7 of the 21.3 mm. male where on one side there are 13 joints and on the other, 14.

Except for secondary sexual characters, the fewer joints which appear to be present in the tarsus, and the more slender peduncle of antenna 1, there are few apparent differences between female and male.

DEVELOPMENT OF JUVENILES OF *Tenagomysis macropsis* AND *T. tenuipes*

The data which follow are additional to Tattersall's and are included in view of the frequency with which catches of juveniles were made and the initial difficulties experienced in their identification. The often large catches indicate that these larval forms make a significant contribution to the plankton of the area and therefore, should be considered in future investigations.

Development appears continuous, there being no clearly definable stages comparable with those of euphausiids. Prior to release from the brood-pouch, in both species, the cephalothorax is relatively larger than the abdomen (due to the presence of more or less yolk from the large egg), the limbs are stouter and less setose, and the proportions of telson and uropods differ from the corresponding adult structures. The changes associated with these during growth are the most noticeable features of development.

*Tenagomysis macropsis* juveniles of 2.2 mm. in length (Fig. 4*a*) are retained in the brood-

TABLE 1  
THE INCREASE IN NUMBER OF TARSAL JOINTS WITH INCREASE IN LENGTH IN *Tenagomysis tenuipes*

LIMB	LENGTH OF SPECIMEN				
	4.2 mm.	8.0 to 9.0 mm.	16.8 mm. (Male)	21.3 mm. (Male)	19.9 mm. (Female)
3.....	2	5	8	9	8
4.....	2	6	9	11	10
5.....	3	6	10	13	11
6.....	3	7	12	13	12
7.....	3	7	13	13-14	12
8.....	2	6	9	10	9



pouch where there may be as many as 25 present. Both antennae 1 and 2 (Fig. 4a, b) are incompletely developed; the squame of antenna 2 (Fig. 4c) is not articulated distally and has only 2 or 3 outer lateral setae; the peduncle of the endopod is not clearly segmented. In the peduncle of antenna 1 (Fig. 4b), segment 2 is slightly longer in comparison to segments 1 or 3 than it is in the adult. Both uropods (Fig. 4d) are setose; the inner is very slightly the shorter, contains the elements of a statocyst, but bears no spines on the inner margin. On the margins of the telson there are 2 or 3 lateral, and 1 terminal, spines; there are 4 to 6 spinules and 2 plumose setae in the cleft. From about 2.5 mm. the young are free in the water and there is a sturdier appearance to the appendages. The cleft of the telson has about 11 spinules (see Fig. 4e, for 2.7 mm. specimen) per side and the statocyst of the inner uropod is better differentiated; the outer uropod is slightly longer relative to the inner one. In 5.0 mm. specimens (Fig. 4f) the outer uropod is noticeably longer than the inner and the latter has developed a series of 6 to 7 spines near the inner margin and several extra setae on the outer; the statocyst is well developed. There is an increase of lateral spines on the telson to 5 or 6 and spinules in the cleft to about 17. In specimens 7.0 mm. long (Fig. 4g) the outer uropod is markedly longer than the inner and on the inside margin of the latter the number of spines has increased to 11. The telson now has 7 to 9 lateral spines and 20 or more spinules in the cleft and is developing a waisted appearance as the basal one-third or so is becoming more bulbous in outline. Between a length of 7.0 mm. and the adult size of 8 to 9 mm. (Fig. 4b) there is a further increase in the number of lateral spines on the telson to 11 or 12, of the cleft spinules to 27 to 30, and of the spines on the inner margin of the inner uropod to about 22.

In addition to these specific changes, there is a progressive lengthening of the limbs and increased definition of cephalic, thoracic, and

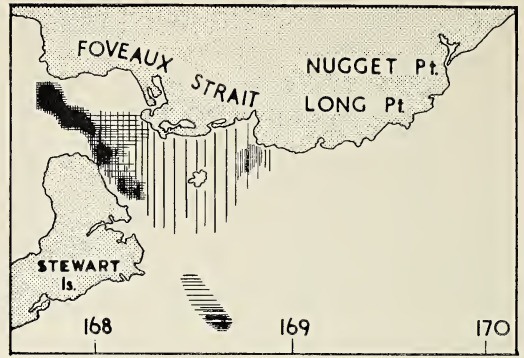


FIG. 6. The distribution of *Tenagomysis macropsis* (vertical lines) and *T. tenuipes* (horizontal lines) about southern New Zealand. Abundance is indicated by the density of the shading.

abdominal regions as adulthood is approached.

In *T. tenuipes* the differences between juvenile and adult are similar in kind to those of *T. macropsis*. In contrast to *T. macropsis* the number of joints in the tarsus of thoracic appendages increases with the age of specimens (Table 1).

Individuals of 8 to 9 mm. (Fig. 5a-g) illustrate the differences to be expected. The telson (Fig. 5d) has 29 to 30 lateral spines, which may be roughly in groups of longer and shorter spines, with the distal ones the more closely spaced and shorter. The cleft has approximately 29 pectinations. The outer uropod is 1.2 times the length of the inner and 1.3 times as long as the telson; the inner uropod has 32 to 35 spines on the inner margin and these tend to be in groups of 3 proximally and to be longer and more widely spaced distally; the outer margin bears secondary setae which are more numerous about the statocyst.

Thoracic limbs 1 and 2 (Fig. 5e, f) are essentially as in the adult. Limbs 3 (Fig. 5g) to 8 are long and slender with reduced numbers of joints in the tarsus. Table 1 indicates the progressive increase in the number of joints in these limbs in specimens ranging in length from 4.2 mm. (about to be shed from the brood pouch) to an adult male of 21.3 mm.

In other features there are slight changes in the proportions of one part with another, e.g., the eyes of smaller specimens are proportionally larger, and the limbs are stouter, but such are usually not of sufficient degree to cause confusion of identity.

The known distribution of both *T. macropsis* and *T. tenuipes* has been extended by the present collections. *T. macropsis* had previously been recorded from northern New Zealand, eastwards almost to Chatham Islands ("Terra Nova," sta. 242), to Dunedin. The present records from Foveaux Strait (Fig. 6) increase the range southward and westward and appear to be consistent with the previous ones.

The range of *T. tenuipes* has been brought 200 miles northward from the Auckland Islands to southern New Zealand, which also involves an increase in temperature of at least 6°C. Both records are from shallow, inshore waters; the species has not been collected between the two areas and may be regarded as a neritic one.

#### DIURNAL VARIATION OF NUMBERS AT THE SURFACE

Tattersall (1936 b), in a short account of vertical distribution, showed diurnal migration occurring for two species of mysids taken by the Great Barrier Reef Expedition. This appears to be the only account of vertical distribution or diurnal movements of mysids for waters of the Southern Hemisphere. Dakin and Colefax (1940: 129) state that a rise to the surface is usual at night, and that probably they collected specimens at no other time. Hardy and Günther (1935) record neither vertical distribution nor migration for the species at South Georgia. There are no previous data for New Zealand mysids.

The data presented below are derived from surface tows and are indicative of vertical migration only through the variation, with time, of numbers at the surface. Further, they are from collections (sta. 74 to 85) made in western Foveaux Strait with the ship at anchor in a tideway wherein the net was streamed for

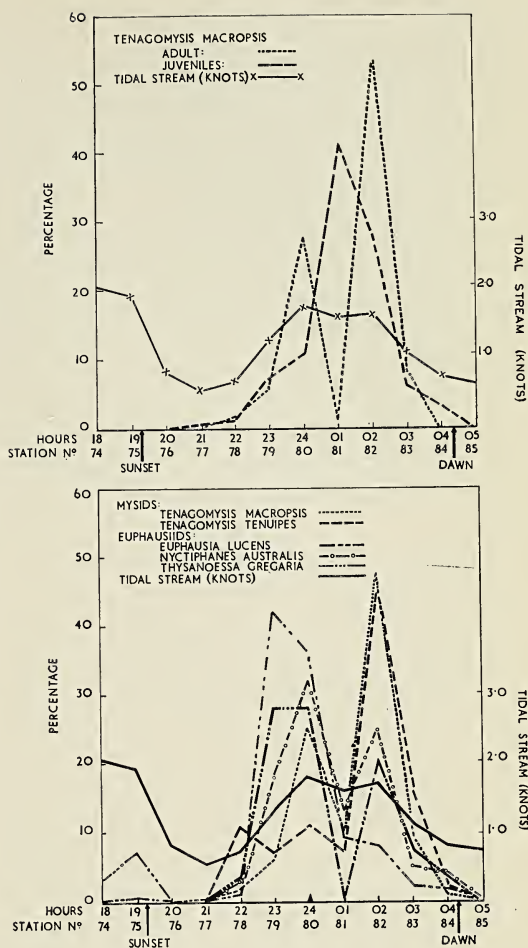


FIG. 7. The variation in numbers of mysids and euphausiids captured in surface tows in a tideway—station series 74–85, western Foveaux Strait. The catch of each species at a station is expressed as a percentage of its total catch for the series. Upper, differential movements of adult and juvenile *Tenagomysis macropsis*. Lower, diurnal variation of mysids and euphausiids.

15 minutes each hour. In this method of working, the velocity of water passing through the net may vary considerably from tow to tow, but in this instance, it was almost constant at from 1.7 to 2 knots between 2400 and 0200 hours (see Fig. 7 in which the rate of flow, computed from hourly observations made from the ship, is plotted) and under half a knot less an hour previous, or subsequent, to these times. Size of catch prob-



ably did vary over the period required to complete the station series because of the velocity changes in the tidal flow, but nevertheless, the variations in numbers taken conform in general to other diurnal migration patterns (Cushing, 1951); especially is this so between 2300 and 0200 hours.

In Figure 7 the curves express the number of specimens per haul as a percentage of all specimens of that species taken in all the hourly hauls. These curves (except for that of juvenile *T. macropsis*—see below) follow a pattern which is normal (Cushing) in that there is a "main rise" with a subsequent decline in numbers which in turn is followed by a later rise and then the descent from the surface.

*Tenagomysis macropsis* (Fig. 7, lower) becomes increasingly numerous from 2100 to 2400 hours when there is a sudden decline to 0100 hours; a second peak of high numbers is reached at 0200 hours followed by a rapid decrease to 0300 hours and then an easing to 0400 hours; at 0500 hours, in full daylight, no specimens were captured. *T. tenuipes* occurred irregularly and in small numbers until 0100 hours. There was no significant increase at midnight (compare with *T. macropsis*), but following a slight decrease in numbers at 0100 hours, which repeats a similar decrease at 2300 hours, there is a sudden increase, coincident with that for *T. macropsis*, to a peak at 0200 hours. The subsequent decline in numbers parallels that of *T. macropsis*.

The great increase in numbers of both species of mysids at 0200 hours coincides with a similar, but not as great, increase in two species of euphausiids, (see later and Fig. 7). As there still remain 2 hours to dawn—first light at 0410 hours—this increase would not appear to be associated with the usual predawn rise, which with Copepoda was indicated by an increased catch at 0300 hours. As this behaviour accorded in the 2 mysid and 2 euphausiid species and as their subsequent reactions were similar, it would appear that for these species, under the conditions ex-

perienced, the rise at 0200 hours was a true expression of their behaviour pattern.

A possibility not to be ruled out in the circumstances is that shoals of the relevant species were being sampled, especially at the 0200 tow, in which case, the appearance of a later, small, predawn rise might be masked by the large catches made earlier. That such shoaling is a not altogether reasonable possibility is demonstrated by the independent migrations to the surface of juvenile and adult *T. macropsis*, shown in the upper graph of Figure 7, where the percentage occurrence of juveniles per haul is superimposed on that for adults from the same hauls. Juveniles increase slowly and steadily to 2400 hours when a sudden increase to a single peak at 0100 hours occurs. The subsequent decline indicates a rapid descent from the surface about the time the late rise of adults commences, although both are at the surface in moderate numbers between 0100 and 0200 hours. The juveniles are also somewhat slower at leaving the surface in this series, as is indicated by a catch of 50 as against 3 adults at station 84.

#### OBSERVATIONS ON THE SYSTEMATICS AND ECOLOGY OF EUPHAUSIIDS

##### Order EUPHAUSIACEA

##### Family EUPHAUSIIDAE

##### Genus EUPHAUSIA Dana

##### *Euphausia lucens* Hansen

Fig. 8

*Euphausia lucens* Hansen, 1905, 1911; Tattersall, 1924; John, 1936.

A few of this species were taken from Cook Strait, but the majority were taken around southern New Zealand. None occurred in the subantarctic stations 795, 826, 921 (Fig. 1). In all 3,378 specimens were captured in 37 hauls.

Sub-mature males and females ranged between 10.0 and 11.0 mm. in length; mature specimens reached 16 mm. and exceptionally, 18 mm.

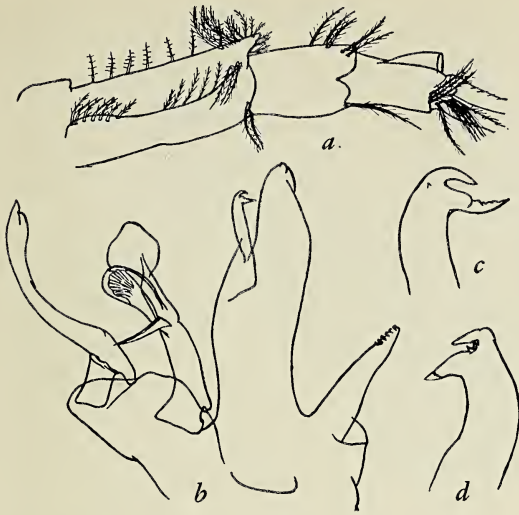


FIG. 8. *Euphausia lucens* Hansen. *a*, Lateral aspect of antenna 1, adult female; *b*, left copulatory organ of 15 mm. male, from behind; *c*, lateral process of left copulatory organ; *d*, lateral process of right copulatory organ.

Features which aid in identification of the species are the broad, triangular lappet (which is variable in size) on the distal inner margin of segment 1, and the shape and size of the keel on the terminal segment, of antenna 1 (Fig. 8*a*); the short, broadly triangular rostrum; absence of dorsal spines on the abdominal segments; and in the male, the detailed structure (Fig. 8*b-d*) of the copulatory organ (John, 1936).

There is a slight discrepancy between John's figures and the present material in the structure of the lateral processes of the copulatory organ (Fig. 8*c, d*). In the present specimens one or more minute, subsidiary spines are in association with the terminal tooth of the process. On the lateral process of the left organ there is, as well, a series of denticulations on the outer surface of the curved end (Fig. 8*c*). Probably these are little more than minor differences as the organs are otherwise identical.

According to Tattersall (1924) *E. lucens* is "a species, the centre of whose distribution lies in the south temperate zone, but which

occasionally penetrates to the subantarctic region." John regards it as primarily a subantarctic species, not found south of the antarctic convergence, and limited by the subtropical convergence in its northward extent. Both authors regard the 12° to 14°C. isotherms as delimiting its northward extension. The difference in terminology lies in Tattersall's acceptance of Regan's (1914) definition of the southern zones wherein northward of the 12°C. isotherm is south temperate, and south of it, subantarctic zones. John regards the waters between the subtropical and antarctic convergences as subantarctic, the temperature of which ranges from 14.5°C. in the north to 4.5°C. in the south over summer months (Deacon, 1937).

In the present collections *E. lucens* extends to stations 322 and 326, north of the subtropical convergence (Figs. 1, 9); at 322 it occurred only in an oblique haul, and at station 326, 10 specimens were taken in the oblique and 6 in the surface tow. At station 330, just south of the convergence, 13 specimens were present in the oblique, and 21 in the surface, hauls. It is a possibility that the oblique tows at 322 and 326 are sampling from concentrations in colder water (11°C.) which was shown by bathythermograph to be present at 40 to 60 metres, and which was a northward extension of subantarctic, overlaid by subtropical, water. The higher numbers in both hauls at 330 appear to support this. Movement northward beyond the convergence in such colder deeper water may in part explain John's statement that specimens occur in the coldest of the subtropical water along the northern edge of the convergence. Contrarily, this species has been taken in water to about 20°C. (John, 1936: 208); with the temperature tolerance which this indicates specimens could penetrate into the overlying warmer water north of the convergence.

Judging from the present collections *E. lucens* appears to be confined to more northerly subantarctic waters (see Fig. 9) than was found by the "Terra Nova" (Tattersall, 1924)



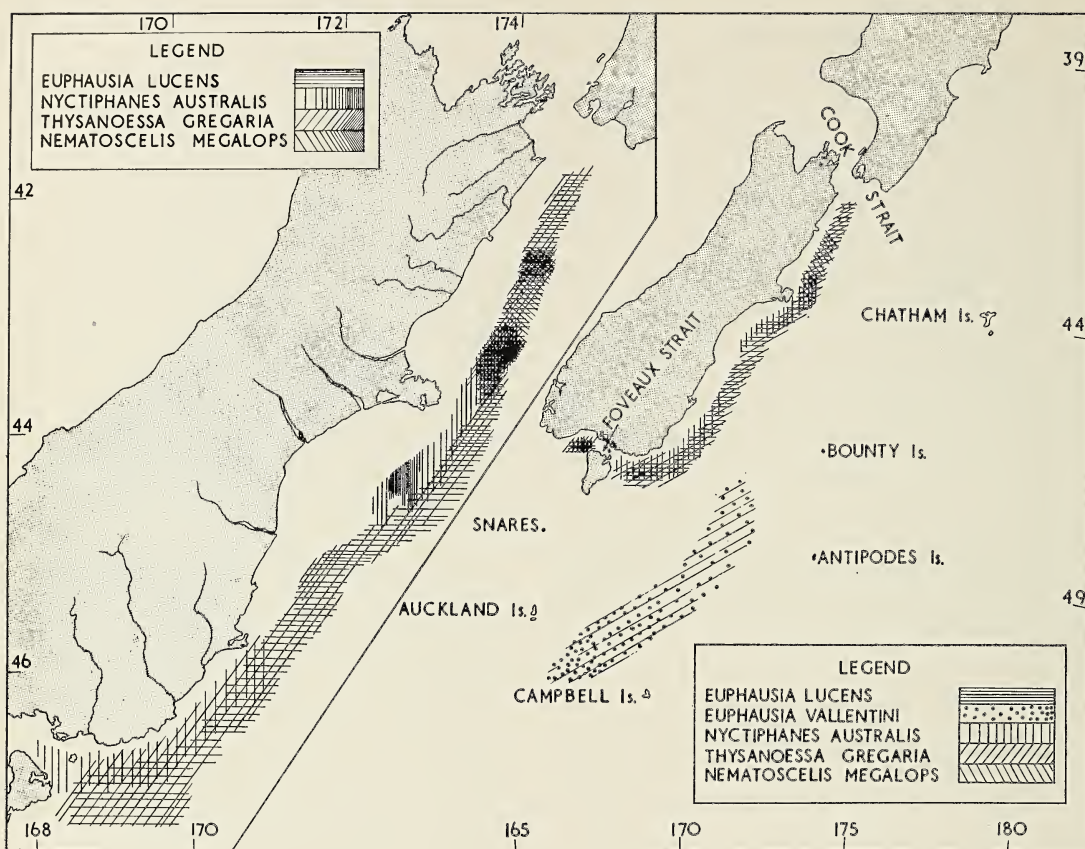


FIG. 9. The distribution of euphausiids between Cook Strait and the Auckland-Campbell Islands area. *Left*, occurrences between Cook and Foveaux Straits. *Right*, occurrences in the sub-antarctic waters in relation to those on the coast of South Island.

or "Discovery II" (John, 1936). No specimens were collected at stations 795, 826 or 921 between southern New Zealand and Auckland Islands—it was replaced by *E. vallentini* (Fig. 9) in these hauls. John (*loc. cit.*) reports, however, that the southern limit of occurrence of *E. lucens* overlaps the northern limit of *E. vallentini*; further sampling is required to show where this occurs to the south of New Zealand.

The pattern of the distribution of *E. lucens* in southern New Zealand waters (Fig. 10) suggests that specimens are entering coastal areas in intruding tongues of subantarctic water. Preponderant occurrence is in a narrow range of salinity between 34.25 and 34.45

parts per thousand which is within that of subantarctic water (34.2 to 34.5 parts per thousand, see Deacon, 1937). Occurrences in water of lower salinities possibly result from intrusions of subantarctic water carrying specimens into dilute coastal water. Some occurrences in waters of higher salinities may be in mixtures with subtropical waters, possibly intruding eastwards through Foveaux Strait.

### *Euphausia vallentini* Stebbing

Fig. 11

*Euphausia vallentini* Stebbing, 1900; Holt and Tattersall, 1906. Hansen, 1911; Tattersall, 1924; John, 1936.

*Euphausia splendens* (part), Sars, 1885.

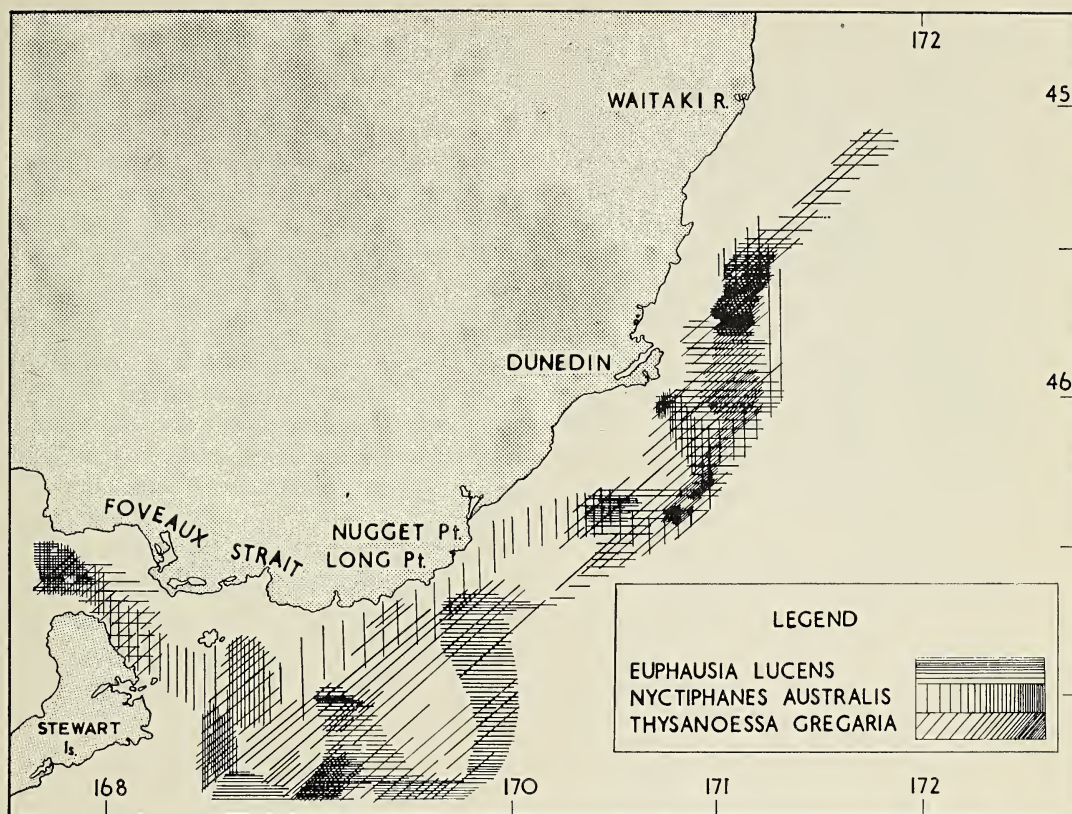


FIG. 10. The distribution of euphausiids, south-eastern New Zealand, for the period January through March, 1951. Abundance is indicated by the density of the shading.

During November 1951, single specimens were taken at each of stations 795 and 826 (at 1900 and 0300 hours respectively) and 24 specimens, including larval stages, at 921 (at 0300 hours). These occurrences (Fig. 9) are in subantarctic waters.

The length of the largest specimen, a female, was 20.5 mm. John (1936) fully describes this species, including larval stages. It is readily identifiable, and also distinguishable from *E. lucens*, by the large, broad, oval lappet distally on segment 1 and the high-arched keel dorsally on segment 3 of antenna 1 (Fig. 11a-c), combined with the presence of the "spine" posteriorly in the mid-dorsal line of abdominal segment 3 and the short, acutely pointed rostrum.

*E. vallentini* is typically associated with subantarctic waters (John). Off New Zealand,

specimens have been taken north of the 12°C. isotherm (Tattersall, 1924) and to about 45°S latitude (John, 1936: 213); both of these occurrences were south of the subtropical convergence, northward of which it has not been recorded. In the present collections, the temperature ranged between 9°C. at 47°37'S, station 795, to 8.2°C. at station 921; since the stations were all kept after nightfall, the 24 specimens collected at 921 would suggest that the species is more common in the colder waters of the higher latitudes in November (see Fig. 9). No specimens have been taken in neritic or near-oceanic waters about southern New Zealand, but it is possible that occasionally it might occur in intrusions of subantarctic water in winter months when the temperature of these waters is appreciably lower.



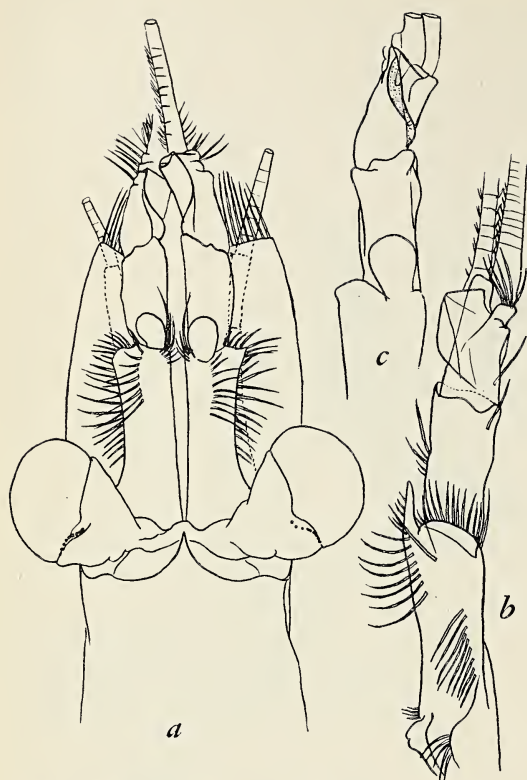


FIG. 11. *Euphausia vallentini* Stebbing. *a*, Antero-dorsal aspect, 20.5 mm. female; *b*, antenna 1, lateral aspect; *c*, antenna 1, dorsal aspect.

#### Genus NYCTIPHANES G. O. Sars

##### *Nyctiphanes australis* G. O. Sars

*Nyctiphanes australis* G. O. Sars, 1883, 1885; G. M. Thomson, 1900; Hansen, 1911; Dakin and Colefax, 1940.

A commonly occurring euphausiid, especially in coastal waters; a total of 3,132 specimens were taken at 28 stations.

Mature females ranged in length from 9.8 to 17.0 mm. and males from 12.0 to 16.0 mm.; thus specimens may mature over a considerable range of size. A very full diagnosis has been given by Sars, 1885; Dakin and Colefax, 1940, illustrate an adult female, a calyptopis, and a furcilia stage.

This species is confined to southeast Australian and New Zealand waters (Hansen, 1911; Tattersall, 1924; Sheard, 1953) and is

regarded as a coastal one. It was collected by "Terra Nova" only in the area about, and south of, Three Kings Islands, just north of New Zealand, but Thomson (1913) recorded it as being extremely common in Otago Harbour, where it was important as a fish food.

The distribution from the present collections is shown to be fairly consistently further inshore than the other euphausiids taken (Figs. 9, 10), although overlap along the margins of the species ranges (especially with that of *E. lucens*) is apparent. Comparatively wide salinity tolerance is demonstrated (34.05 to 34.72 parts per thousand), and preference is shown for temperatures, for the most part, above 13.5°C. These data lend support to Tattersall's claim that *N. australis* is a coastal species. The species was absent in tows north of the subtropical convergence, but the earlier records suggest that it may be common throughout our coastal waters.

#### Genus THYSANOESSA Brandt

##### *Thysanoessa gregaria* G. O. Sars

Fig. 12

*Thysanoessa gregaria* G. O. Sars, 1883, 1885; Hansen, 1911, 1913; Dakin and Colefax, 1940; Einarsson, 1945; Boden, 1954.

A total of 1,256 specimens were taken, mostly in small numbers, at 42 stations; large catches were made only in a night series between Dunedin and Nugget Point (stations 285 to 308; Figs. 1, 9, 10).

The longest specimen was a 16.2 mm. female, but the majority of adults, which were comparatively rare, were between 10 and 13 mm. long; most specimens captured were either furcilia or cyrtopid stages.

The adult possesses a characteristic denticulate plate, the pre-anal spine (Sars, 1885), which, together with the stout form of the body, very long second leg (Fig. 12*b*), large eye, and in the male, the copulatory organ (Fig. 12*a*), contributes to ready identification of the species.

Sars reported *Tb. gregaria* from "Challenger" collections made between Sydney and Wellington, Chilton (1911) found it in stomachs of fish from the Kermadec Islands, and Tattersall recorded it in "Terra Nova" catches from south of Three Kings Islands. The latter collections, some 250 specimens from 20 stations, comprised the largest catches until those of the present series. The species is regarded as typically from northern or southern temperate waters (Hansen, 1911; Tattersall, 1924; Einarsson, 1945; Boden, 1954). Although in the southern hemisphere it has several times been recorded in subantarctic waters, i.e., south of the 6°C. isotherm in Regan's (1914) terminology (see Hansen 1913, and Tattersall, 1918) Boden, following an extensive survey, regarded it as a "true temperate or subtropical form" and states that its occurrences in African subantarctic water were "probably transitory."

In the present collections specimens occurred from Cook Strait to latitude 51° 41'S (station 921 where 30 were collected; Figs. 1, 9); at only six stations were more than 50 specimens taken at one time and of these, stations 210, 297, and 308 had 195, 200, and 496 specimens, respectively. Its consistent penetration into coastal water (Fig. 10) in which temperatures of 15°C. and higher were met, and its presence in subantarctic water of as low as 8.2°C. indicate a considerable temperature tolerance. However, largest catches were made in oceanic water with salinity and temperature characteristics of the subantarctic, suggesting that the species may occur there more frequently than previously thought.

#### Genus NEMATOSCELIS G. O. Sars

#### *Nematoscelis megalops* (?) G. O. Sars

Fig. 13

*Nematoscelis megalops* G. O. Sars, 1883, 1885; Hansen, 1911, 1915; Esterley, 1914a; Banner, 1949; Boden, 1954; Boden, Johnson and Brinton, 1955.

A total of eight females was taken, two from the horizontal and five from the oblique tows at station 326, and one from the oblique tow at station 330 (Figs. 1, 9).

According to Hansen (1911), Banner (1949), Boden (1954), and Boden, *et al.* (1955), the only means of separating the Atlantic species *N. megalops* from *N. difficilis* of the northeast Pacific, is on the structure of the male copulatory organ. On the other hand Einarsson (1942), from a study of the spermathecae of the two species, regards them as identical. Most unfortunately, no male was taken here, and because of this the identification is left open; but the evidence presented in Table 2 appears to favour the specimens being identified as *N. megalops*. The notes for *N. difficilis* are derived from Esterley (1914a), Banner (1949), and Boden, *et al.* (1955).

Table 2 lists characters which vary between the two species, suggesting that differences may exist other than those found in the male



FIG. 12. *Thysanoessa gregaria* G. O. Sars. *a*, Left copulatory organ of adult male, from behind; *b*, first and second thoracic limbs.





FIG. 13. *Nematoscelis megalops* (?) G. O. Sars; 20.4 mm. female. *a*, Lateral aspect; *b*, telson and uropods; *c*, antennae 1 and 2; *d*, terminal portion of limb 2.

copulatory organs. The median spine-like processes on the fourth and fifth abdominal somites, (or the median keel in the *N. Z.* specimens?) may prove a convenient distinguishing character in view of their absence (Banner) in *N. difficilis*.

*Nematoscelis megalops* has been described as one of the characteristic euphausiids of the northwest Atlantic according to Hansen (1911) who mentions that it has also been recorded "at some places in the southern temperate Atlantic," but that females taken in the southern Indian Ocean could not be referred to either *N. megalops* or *N. difficilis*. Boden (1954) reports that *N. megalops* is common about South Africa, but that no records exist of it from the south Pacific. On the other hand, Sheard (1953) records *N. difficilis*,

adults and larval stages, as commonly occurring in east Australian waters. He also, doubtfully, records *N. megalops* from the western Indian Ocean.

Specimens of *N. megalops* from the south Atlantic could well get caught up in the West Wind Drift and attain a sparse, subantarctic circum-global distribution, eventually reaching southern New Zealand in the subantarctic water. It is equally possible for *N. difficilis* to be carried into the area from Australia, either in the West Wind Drift, or (and more likely) across the south Tasman Sea via the western drift in that portion of the ocean.

Thus it is possible for either, or both, *N. megalops* and *N. difficilis* to be present in New Zealand waters. Recorded distributions, and more especially proximity to Australia and

direct oceanographic communication from Australia to New Zealand, suggest that the New Zealand specimens may be *N. difficilis*. The morphological features listed in Table 2, however, favour their being *N. megalops* and accordingly the species is provisionally listed as *N. megalops*.

EUPHAUSIID LIFE HISTORIES

There are numerous accounts of larval development of a wide range of species of the Euphausiacea. Einarsson (1945) has treated the historical progress in these studies and has reviewed the terminology of the developmental phases. Gurney (1947) reviews development. Sheard (1953) briefly covers historical features and theories of development; he also discusses "dominance" among larval instars and questions the validity and usefulness of the concept. Boden (1955) discusses in turn Sheard's view towards dominance and also his "lumping" of the numerous furciliae of *N. australis*, and those of other species into three furcilia stages. Boden is of the opinion that dominance is still a useful concept, and that, "under the present circumstances it is

less useful to 'lump' the furcilia stages than to 'split' them."

Some life-history stages are available from the "Lachlan" material for *Nyctiphanes australis* and *Thysanoessa gregaria*; the three calyptopis, and a complete series of furcilia stages for *Euphausia lucens*. There is little doubt that in the present material dominant instars occur for the oceanic species *E. lucens* and *T. gregaria*. For the coastal species *N. australis*, a tendency for dominant instars to occur is explained as due to the local nature of the collections (see Sheard, 1953); Sheard's grouping of the instars has been followed for this species.

Development of *Euphausia lucens*

John (1936) combines *Euphausia crystallophias*, *E. superba*, *E. frigida*, *E. vallentini*, and *E. lucens* into a group of related species (his "Southern Group"); of these, closest relationship is considered to exist between *E. lucens*, *E. vallentini* and *E. frigida*. He describes the development of *E. vallentini* and *E. frigida* (but not of *E. lucens*) and the close relationship of adults of the two species is reflected in the similarity of their development

TABLE 2  
DIAGNOSTIC CHARACTERS OF *Nematoscelis difficilis* AND *N. megalops* (FROM VARIOUS AUTHORS) AND THEIR COMPARISON WITH FEMALE *Nematoscelis* FROM NEW ZEALAND

CHARACTER	<i>N. difficilis</i>	<i>N. megalops</i>	<i>N. megalops</i> (?)
Ratio of lengths of segments 1 to 3 of antenna 1	1 : 0.6 : 0.65	1 : 0.5 : 0.45	1 : 0.47 : 0.45
Squame	Reaches to half length of segment 3 of antenna 1	Reaches to end of segment 3 of antenna 1	Reaches almost to end of segment 3 of antenna 1
Ratio of length of telson to abdominal somite 6	3.8 : 2 (Boden <i>et al.</i> 1955, fig. 40a)	3 : 2	3 : 2
Dorsal armature on abdomen	Denticles not present	Small, mediodorsal spine-like processes on 4th and 5th somites	Low, mediodorsal keels on 4th and 5th abdominal somites which terminate in a short spine-like process on the posterior margin of each of the somites



TABLE 3  
COMPARISON OF LARVAL CHARACTERS OF *Euphausia frigida*, *E. valleritini*, *E. lucens* AND (?) *E. lucens* FROM SOUTH AFRICA

STAGE	CHARACTER	<i>E. frigida</i>	<i>E. valleritini</i>	<i>E. lucens</i>	(?) <i>E. lucens</i>
<i>Calyptopis</i> I-III . . . . .	Carapace	Smooth, rounded frontal margin; no posterior spine; lateral denticles in Stage III.	Same as <i>E. frigida</i>	Same as <i>E. frigida</i>	Strongly spinose, very broad, rounded and medially cleft. Large postero-dorsal spine. Lateral denticles present, all stages.
	Length, mm.	I . . . . . II 1.7-1.8 III 2.5-2.9	. . . . . 1.6-1.8 2.5-2.8	0.9-1.2 1.4-1.7 2.1-2.5	0.98-1.0 1.3-1.8 2.10-2.33
<i>Parvula</i> I . . . . .	Frontal plate	Broadly rounded, non-spinose	Angularly rounded, non-spinose	Broadly rounded, non-spinose	Very broad, strongly spinose margin, medially cleft.
	Pleopods Telson spines Length, mm.	4 non-setose 3.8-4.3	4 non-setose 3.2-4.0	4 non-setose 2.7-3.2	1 non-setose 7 3.0
II . . . . .	Pleopods Telson spines Length, mm.	4 setose, 1 non-setose 7 4.7-5.7	4 setose, 1 non-setose 7 4.5-5.1	4 setose, 1 non-setose 7 3.4-4.1	1 setose, 4 non-setose 7 3.5
	Pleopods Telson spines Length, mm.	5 setose 7 5.5-6.7	5 setose 7 5.4-6.1	5 setose 7 4.0-5.0	5 setose 7 .....
IV . . . . .	Pleopods Telson spines Endopod of antenna 2 Length, mm.	5 setose 5 segmented 6.5-7.7	5 setose 5 segmented 5.4-6.1	5 setose 5 segmented 4.7-5.5	5 setose 5 unsegmented .....
	Telson spines Endopod of antenna 2 Length, mm.	3 ..... 7.0-8.3	3 ..... 6.1-7.6	3 ..... 5.0-6.1	3 segmented .....
VI . . . . .	Telson spines Length, mm.	1 6.8-9.6	1 6.2-9.3	1 5.0-6.0	1 .....

(see Table 3). It might be expected that *E. lucens* would also exhibit a developmental series similar to those of *E. frigida* and *E. vallentini*, and the New Zealand material proves this to be so.

Boden (1955) has described the calyptopis and the first two furcilia stages (with brief notes on later stages) of what was believed to be *E. lucens*, from a small amount of material collected in the area of the Benguela Current. The developmental series of his material is widely at variance with the species relationship discussed above, and it would appear that the species described may be other than *E. lucens*. The New Zealand material supports such an opinion. It supplies a continual series of stages from calyptopis to adult *E. lucens* which, even though similar to *E. frigida* and *E. vallentini*, is unlikely to be confused with developmental stages of these species inasmuch as *E. frigida* is only exceptionally found north of the antarctic convergence and no adults of *E. vallentini* were captured in the waters where *E. lucens* was abundant. Further, furciliars of *E. lucens* are considerably smaller, especially in later stages, than for the other species, see Table 3.

Relevant information for comparing *E. lucens*, *E. frigida*, *E. vallentini* and Boden's material is summarised in Table 3.

The stages of *Euphausia lucens* obtained, following John's (1936) system of nomenclature, are as follows:

*Calyptopis*: Stages I, II, and III.

*Furcilia*:

- Stage I. With four pairs of non-setose pleopods.
- Stage II. With four pairs of setose, one pair of non-setose pleopods.
- Stage III. With five pairs of setose pleopods; 5 terminal spines to telson; endopod of antenna 2 unsegmented.
- Stage IV. Telson with 5 terminal spines; endopod of antenna 2 segmented; squame differentiated.

Stage V. Telson with three terminal spines.

Stage VI. Telson with one terminal spine.

FIRST CALYPTOPIS: (Fig. 14*a-e*). Length, 0.9 to 1.2 mm. (average 1.0 mm., 9 specimens measured).

The carapace (Fig. 14*a*) is rounded at frontal and posterior margins, longer by one-third than the abdomen, and without lateral denticles. The peduncle of antenna 1 is not segmented. There are indications of segmentation on the abdomen. The telson is short (Fig. 14*b*) with 7 terminal spines and 4 pairs of lateral spines of which the anterior pair is ventrolateral. The mandible, and maxillae 1 and 2 are illustrated (Fig. 14*c, d, e*). The first thoracic limb is segmented, and the terminal portion is bifurcate.

SECOND CALYPTOPIS: (Fig. 14*f, g*). Length, 1.4 to 1.7 mm. (average 1.6 mm., 15 specimens measured).

The carapace possesses a small dorsal organ and no lateral denticles; it is broadly rounded anteriorly and posteriorly (Fig. 14*f*), slightly constricted behind the eyes, widest in the posterior half and is almost as long as the abdomen. Thoracic segments 2 to 8 are visible as narrow annulations between the first thoracic limb and the abdomen which has five segments. The telson (Fig. 14*g*) is as described for the first calyptopis, but is longer and more slender; there are no uropods. The peduncle of antenna 1 (Fig. 14*f*) has 2 or 3 segments; one of the flagellae is represented by the terminal portion of the ultimate segment of the peduncle, the other by a minute segment. The eyes are rudimentary and covered by the carapace. The maxillae and limb 1 are essentially as in Stage I.

THIRD CALYPTOPIS: (Fig. 14*h, i*). Length, 2.1 to 2.5 mm. (average 2.3 mm., 14 specimens measured).

The carapace possesses a dorsal organ and a small posterolateral denticle on each ventral margin; the anterior margin is squarer, the posterior margin more rounded than in the



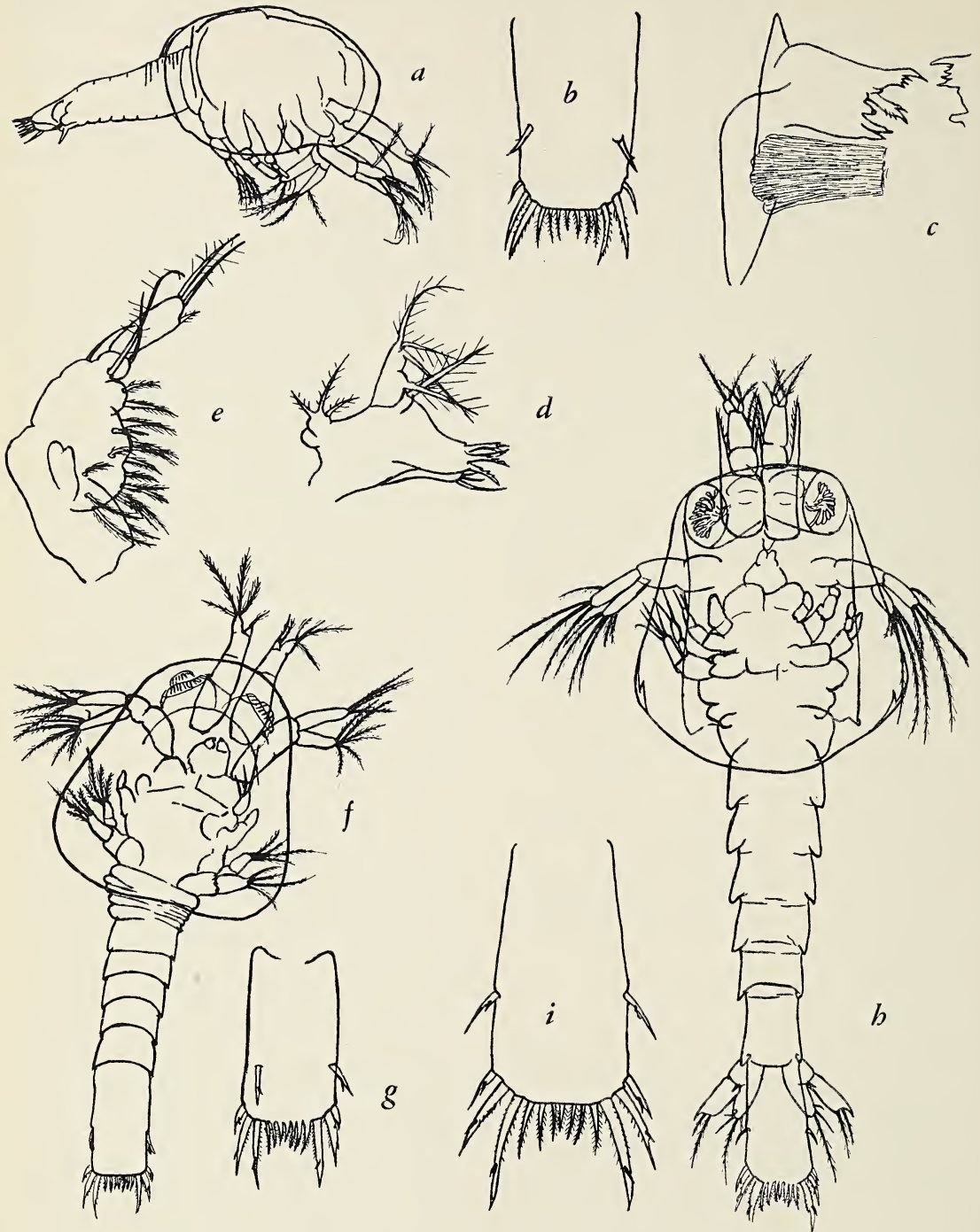


FIG. 14. Calyptopis stages of *Euphausia lucens* Hansen. *a-e*, Stage I: *a*, Lateral aspect of 1.0 mm. specimen; *b*, telson; *c*, mandible; *d, e*, first and second maxillae. *f, g*, Stage II: *f*, Dorsal aspect of 1.5 mm. specimen; *g*, telson. *h, i*, Stage III: *h*, Dorsal aspect of 2.4 mm. specimen; *i*, telson. *a, f, g*,  $\times 50$ .

previous stage, but the slight constriction is still present behind the eyes; it is much broadened posteriorly (Fig. 14*b*). On segment 1 of the peduncle of antenna 1 there is a well-developed lateral spine which reaches to the end of segment 3; both flagellae are segmented off from the peduncle. The eyes are well defined and becoming pigmented but are still covered by the carapace. The abdomen has 6 segments and a telson, and is 1.5 times the length of the carapace. There are 7 terminal spines on the telson (Fig. 14*i*) which is flanked by inner and outer uropods. There are rudiments of limbs enclosed in a common sheath posterior to limb 1.

Stages II and III are very similar to the corresponding stages for *E. frigida* and *E. vallentini* (see John, 1936, who does not describe Stage I). That they are not of these species must be assumed from the facts, firstly that no adults of either were taken as far north as southern New Zealand, where these calyptopids were captured, and secondly, that the furciliars with which they are continuous are smaller than those for either *E. frigida* or *E. vallentini*.

FURCILIA, STAGE I: (Fig. 15*a-d*). Length 2.7 to 3.2 mm. (average 3.0 mm., 17 specimens measured).

This stage has 4 pairs of non-setose pleopods and 7 terminal spines on the telson. The carapace (Fig. 15*a, b*) possesses a distinct dorsal organ, lateral denticles, and anterodorsal spines; the rostral plate is as wide as long, or wider, with the frontal margin slightly rounded. The spine on the outer distal corner of segment 1 of antenna 1 is usually as long as segments 2 and 3 combined, but may reach only halfway along segment 3. The first thoracic limb is bifurcate; the second (Fig. 15*c*) is rudimentary, with elements of exopodite and gill developing; other limbs are buds enclosed in a common sheath (Fig. 15*d*). Uropods reach to, or almost to the first pair of lateral spines (Fig. 15*d*) which are situated at between one-half and two-thirds the length of the telson.

FURCILIA, STAGE II: (Fig. 15*e-g*). Length, 3.4 to 4.1 mm. (average 3.8 mm., 28 specimens measured).

This stage is characterised by 4 pairs of setose and 1 pair of simple pleopods, and 7 terminal spines on the telson. The rostral plate is rounded, or angularly rounded (Fig. 15*e*), is broader at the base than long, and usually has a minute terminal spine. Thoracic limb 2 (Fig. 15*f*) comprises 3 or more segments, is setiform and possesses a rudimentary exopodite and gill; limb 3 is a kneed rudiment and has a rudimentary gill; limbs 4 to 6 exist as buds. The distolateral spine of segment 1 of antenna 1 extends to halfway or more along segment 3. The first abdominal segment has a pronounced tergal wing extending dorsally and laterally (Fig. 15*e*). The telson (Fig. 15*g*) is 4.5 times as long as wide and inner and outer uropods reach to, or a little beyond, the lateral spines.

FURCILIA, STAGE III: Length, 4.0 to 5.0 mm. (average 4.7 mm., 16 specimens measured).

There are 5 setose pleopods and 5 terminal spines (6 in two specimens) on the telson. The rostral plate is similar to that of the previous stage. The endopod of antenna 2 is unsegmented. The distal spine of segment 1 of antenna 1 extends for half, or less, of the length of segment 3; the flagellae are elongating. The endopod (inner ramus) of thoracic limb 1 is elongating; limb 2 is setiform and possesses 3 tarsal joints (sub-segments); limb 3 may have 3 joints or be indistinctly segmented in the tarsus; limb 4 is kneed, 2-segmented and with elements of gill and exopodite; limbs 5 and 6 are rudiments. The outer uropod is as long as the inner which reaches from one-third to halfway between the lateral and the first (outer) post-lateral spines; the inner has 3 or 4 setae on its outer margin. The inner pair of post-lateral spines are broadening basally.

FURCILIA, STAGE IV: (Fig. 15*h-j*). Length, 4.7 to 5.5 mm. (average, 5.2 mm., 6 specimens measured).



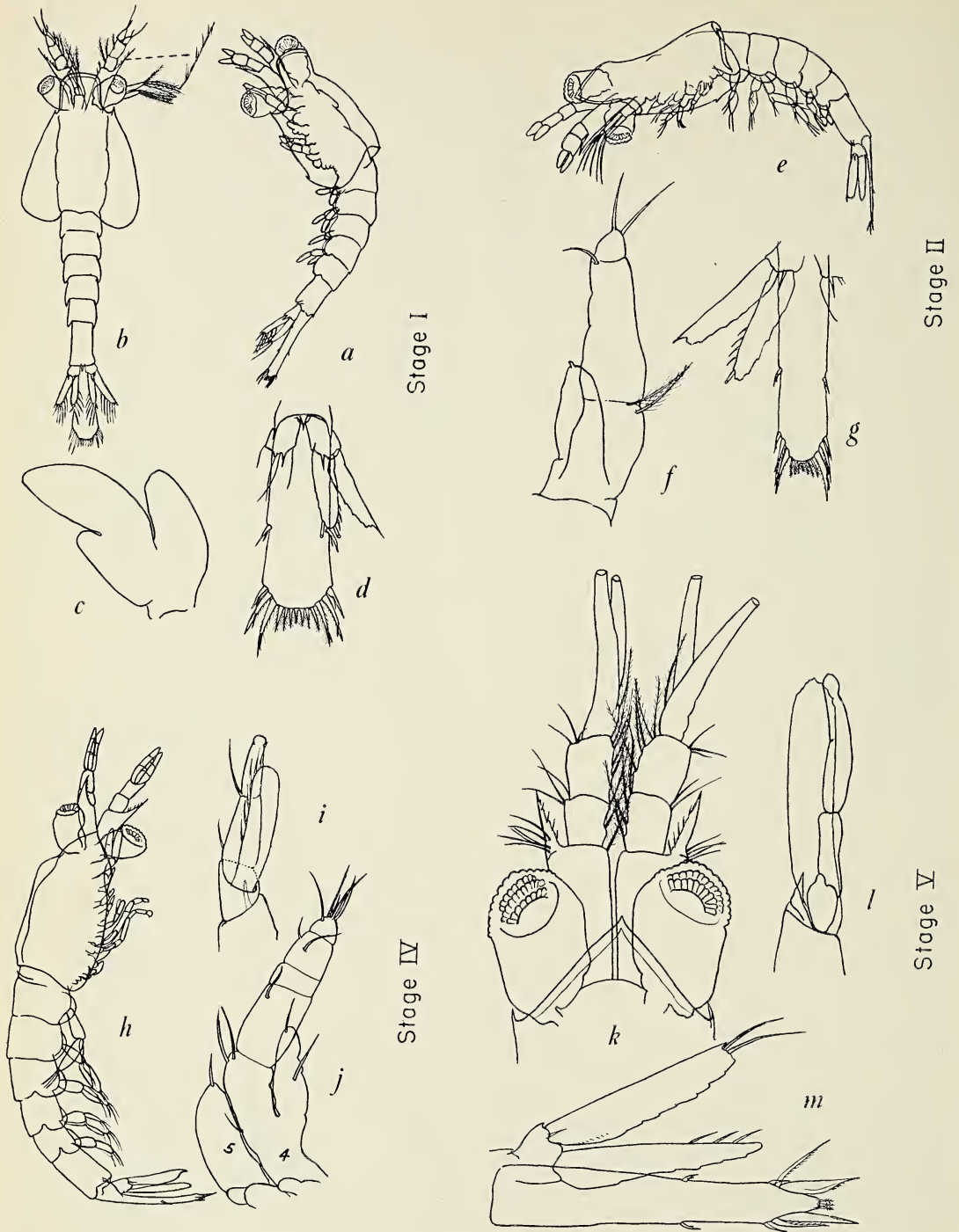


FIG. 15. Furcilia stages of *Euphausia lucens* Hansen. a-d, Stage I: a, Dorsolateral aspect of 3.2 mm. specimen; b, dorsal surface; c, second thoracic limb; d, telson and uropods. e-g, Stage II: e, Dorsolateral aspect of 4.0 mm. specimen; f, second thoracic limb; g, telson and uropods. h-j, Stage IV: h, Dorsolateral aspect of 4.6 mm. specimen; i, antenna 2 showing segmented flagella and the squame; j, thoracic limbs 4 and 5. k-m, Stage V: k, Antero-dorsal aspect of 5.5 mm. specimen; l, antenna 2, endopod and squame; m, telson and uropods.

There are 5 setose pleopods, 5 terminal spines on the telson, and the endopod of antenna 2 is segmented (Fig. 15*i*). The rostral plate (Fig. 15*b*) is more triangular, with less convex margins than in Stages II or III, and it has a small terminal spine. There is a pronounced dorsal organ on the carapace. The squame of antenna 2 is differentiated; it is setose on its inner margin and without a distolateral spine; the spine arising from the basal segment is present. The segmented endopod is beginning to elongate. The first abdominal somite possesses tergal wings. Thoracic limb 1 is bifurcate distally; the second and third limbs are fully segmented, and each has a setose exopodite and a gill. Limb 4 (Fig. 15*j*) is 3- or 4-segmented, with a rudimentary exopodite which has 2 setae, and a rudiment of a gill. Limb 5 (Fig. 15*j*) is short, kneed, with a terminal seta, and rudiments of gill and exopodite; limb 6 is rudimentary.

FURCILIA, STAGE V: (Fig. 15*k-m*). Length, 5.0 to 6.1 mm. (average, 5.4 mm., 15 specimens measured).

This stage has 3 (rarely 2) terminal spines on the telson. The rostral plate (Fig. 15*k*) is triangular, almost straight sided, with a minute terminal spine. The spine on segment 1 of antenna 1 is somewhat longer than the second segment of the peduncle (Fig. 15*k*). The endopodite of antenna 2 is segmented and the squame is as long as the endopod. Limbs 1 to 4 are better developed than in the previous stage; limb 5 is segmented, short and kneed; limb 6 is a kneed rudiment which may be segmented. The telson is 5 times as long as wide (Fig. 15*m*) and the inner post-lateral spines are becoming conspicuously broadened. The outer uropod is as long as the inner and they reach almost to the base of the outer pair of post-lateral spines.

FURCILIA, STAGE VI: Length, 5.0 to 6.0 mm. (average 5.6 mm., 15 specimens measured).

There is one terminal spine on the telson (rarely 2). The rostral plate is broadly triangular and acutely pointed. The spine on

segment 1 of antenna 1 is usually present and extends almost to the end of segment 2 of the peduncle. The endopod of antenna 2 has 3 segments, and there are indications of the segmentation of the flagella in the terminal segment. Thoracic limb 5 has a 3-jointed tarsus; limb 6 is kneed, with 2 segments and elements of exopodite and gill; limb 7 is a bud with a gill, and there is a single gill rudiment at the position of limb 8. The telson is slender and the outer post-lateral spines are much reduced, the middle pair are long and slender, the inner pair are broadened proximally, and curve outward in the distal half. The uropods are subequal in length and reach to the base of the post-lateral spines; the inner has 4 to 6 setae on its outer margin.

POST LARVAL STAGE: (Fig. 16). The specimen figured (Fig. 16*a*) is 7.5 mm. long and was readily identifiable as *E. lucens*. The terminal portion of the telson (Fig. 16*b*) is acutely pointed and has one pair of large latero-terminal spines which bear small secondary spines distally. Inner and outer uropods are equal in length, but are not as long as the telson. There is a pre-anal spine with 2 teeth. Antenna 1 (Fig. 16*c*) is developing a keel on segment 3 and a small, distinct, triangular lappet on segment 1. The squame of antenna 2 (Fig. 16*c*) is longer than the combined segments 1 and 2 of the peduncle of antenna 1, and has a long spine at the base. The rostrum is proportionately longer and more acutely pointed than that of the adult. The thoracic limbs are as in the adult, including the modified setae on the distal segment of limb 2 (Fig. 16*d*). The mandible has a well-developed cutting plate and palp, and maxillae 1 and 2 are similar to those in the adult.

#### *Development of Nyctiphanes australis*

Sheard (1953) reviews the state of knowledge on the development of *Nyctiphanes australis*, and presents a series of detailed diagrams illustrating variation in the order of development of pleopods, and in the loss of



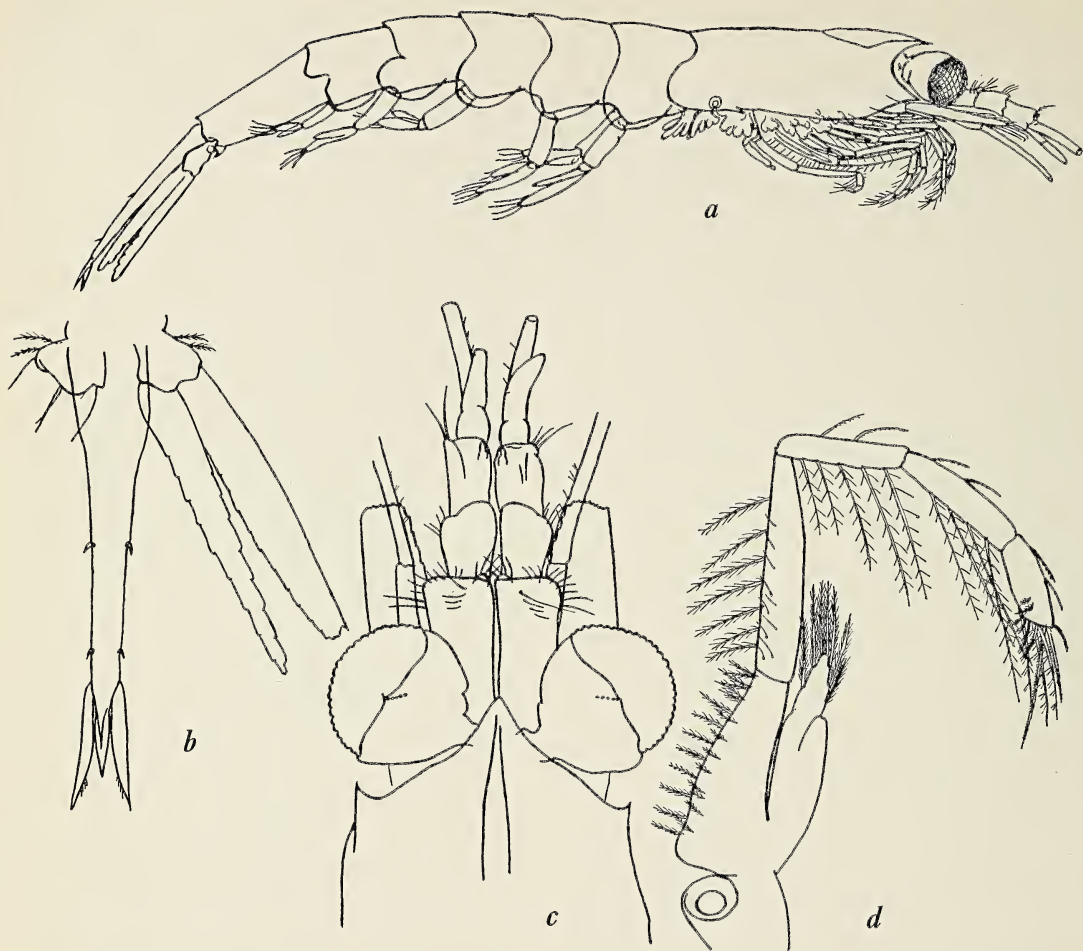


FIG. 16. Mid post-larval stage of *Euphausia lucens*. *a*, Lateral aspect of 7.5 mm. specimen; *b*, telson and uropods; *c*, anterodorsal aspect; *d*, second thoracic limb.

telson spines. In this, as in previous accounts of development in this species, little attention has been paid to other morphological changes. Inasmuch as morphology is necessary for the certain identification of the larvae of *N. australis*, the present account deals with this, especially of the thoracic limbs and their differentiation during the furcilia stages. The account is not exhaustive, but is representative of a range of instars from each of the furcilia stages. The designation of the furciliae, and the instars composing them, are those proposed by Sheard; the present ma-

terial, although restricted in quantity, suggests that his furcilia stages meet the requirements of this species.

By means of his diagrams Sheard demonstrates that the number of instars preceding some later instar (for example, that with 5 setose pleopods and 7 terminal spines on the telson) may vary. This condition has not been otherwise commented on, although the present material suggests that it is important. It appears to lead to variations in the degree of differentiation of the thoracic limbs and antennae among specimens which have been

designated a single instar by other characters. This occurs in the later instars of Furcilia II, and in Furcilia III instars. Thus in the "Lachlan" material, the instar with 4 setose and one non-setose pleopods is composed of two groups of specimens, one of which is further advanced than the other in its limb development, probably because specimens have undergone an additional earlier ecdysis. It is possible that further groups could have been identified from more extensive material. Sheard recognises that the group of specimens with 5 setose pleopods and 7 terminal spines on the telson is comprised of individuals from two instars. One of these, in which the endopod of antenna 2 is not segmented and the inner post-lateral spine of the telson is not broadened, he identifies as belonging in Furcilia II (his 5S7Sp A); the other, wherein the endopod is segmented and the inner post-lateral spine is broadened, is assigned to Furcilia III (his 5S7Sp B). In "Lachlan" specimens a third group, belonging in Furcilia II (and which, in itself, may have been a miscellany of development stages), is present. These specimens were intermediate between Sheard's two groups in their limb and antennal development, but retained the pleopod and telsal differentiation typical of this group of instars (5 setose pleopods, 7 terminal spines on the telson).

This type of complexity extends into the other instars of Furcilia III. It is convenient to identify those instars in which multiple stages of limb development are present as "instar-groups," while each of the stages composing such a group is an instar. This classification possibly has a factual basis, although insufficient material has defeated attempts to trace the development paths leading up to these complexities. However, Sheard's diagrams of development series for *N. australis* suggest possibilities which might produce such a result. More will be said of this type of parallelism in development in the discussion of Furcilia II and III in the following.

FURCILIA, STAGE I: (Fig. 17a-d). The number of pleopods and telsal spines present and the size of all specimens in the "Lachlan" material are given in Table 4. In all instars of this stage the pleopods are non-setose.

The morphological changes between successive instars are progressive, but not extensive. The wide frontal plate of the carapace (Fig. 17b) covers approximately half the eye and stalk, is broader basally than long, and is squarely truncate anteriorly. The carapace is medially emarginate posteriorly and has a denticle on each lateral margin; stout antero-ventral spines are present. The telson (Fig. 17c) has 7 terminal spines, 1 pair of lateral and 3 pairs of post-lateral spines. The ratio of length of telson to its width ranges between 2:1 for specimens with one pair of pleopods to 7:3 for specimens with four pairs; the telson is twice the length of the sixth abdominal somite and the lateral spines are placed at between one-half and two-thirds its length.

The thoracic limbs develop progressively with each instar, and those already differentiated increase in complexity. Limb 1 is biramous throughout the instars, the inner ramus (endopod) being 2-segmented. Limb 2 develops from a stout, unsegmented, kneed rudiment to a kneed, 3-segmented structure with elements of a gill and exopodite. Limb 3 grows from a bud to an elongate rudiment with exopodite and gill as bud-like swellings; limb 4 is an elongated bud in the 4-pleopod instar. The distal spine of the basal segment of the peduncle of antenna 1 (Fig. 17b) reaches beyond the mid-length of segment 3; both flagellar rudiments are segmented off at instar 2, but only the inner in the first instar.

FURCILIA, STAGE II: (Fig. 17e-l).

Table 5 presents the data on pleopods and telsal spines and size of the "Lachlan" material and demonstrates that specimens with 4 setose and 1 non-setose and those with 5 setose pleopods and with 7 terminal telsal spines are 'instar-groups,' not single instars. Two instars, identified by differing states of



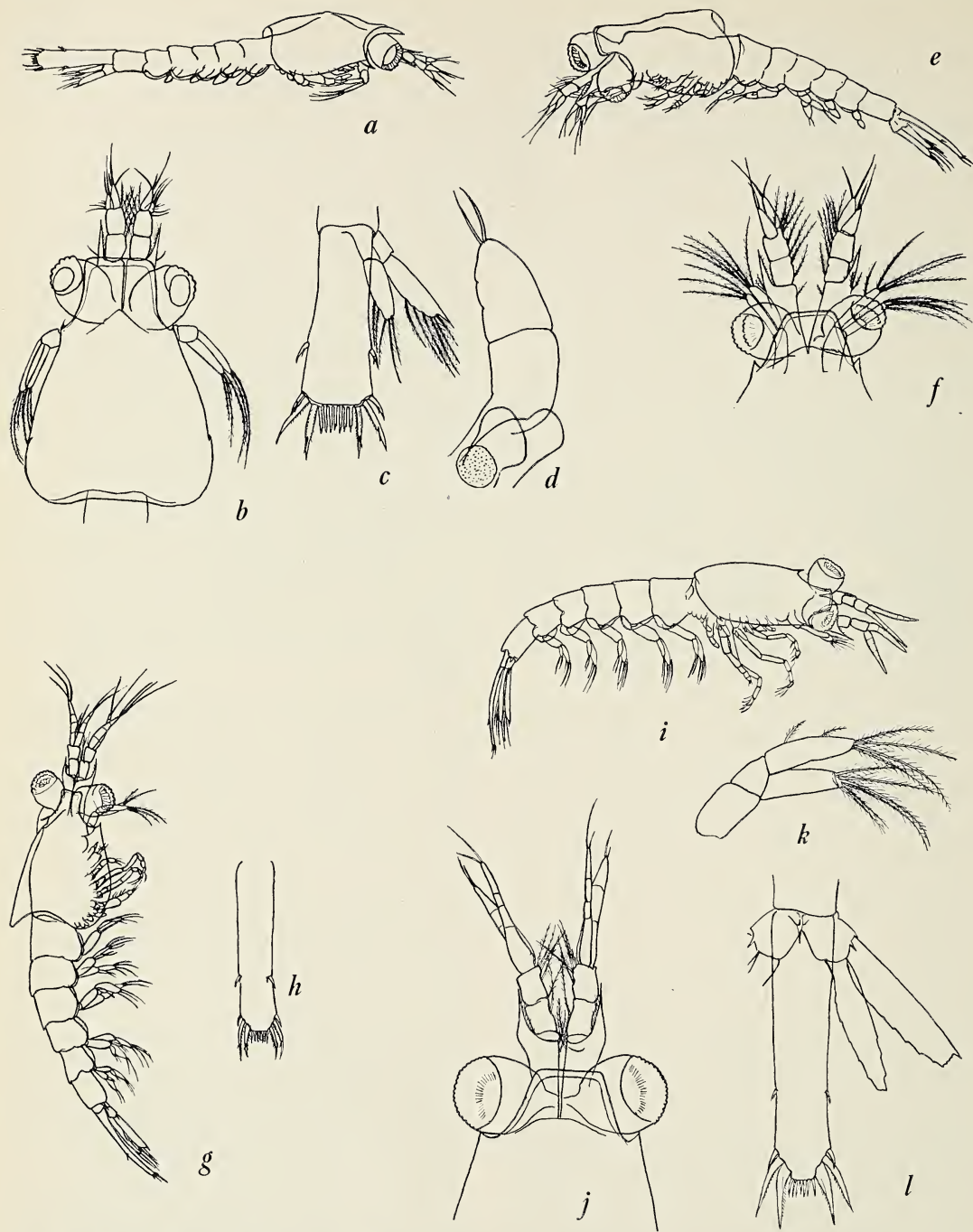


FIG. 17. Furcilia stages of *Nyctiphanes australis* G. O. Sars. *a-d*, Stage I with 4 non-setose pleopods: *a*, Lateral aspect of 2.9 mm. specimen; *b*, anterodorsal aspect; *c*, telson and uropods; *d*, rudimentary limb 2. *e, f*, Stage II with 3 setose and 2 non-setose pleopods: *e*, Dorsolateral aspect of 3.5 mm. specimen; *f*, anterodorsal aspect. *g, h*, Instar A, Stage II, from the instar-group with 5 setose pleopods and 7 terminal spines on the telson: *g*, Dorsolateral aspect of 4.2 mm. specimen; *h*, telson. *i-l*, Instar A', Stage II, from the instar-group with 5 setose pleopods and 7 terminal spines on the telson: *i*, Dorsolateral aspect of 4.3 mm. specimen; *j*, anterodorsal aspect; *k*, unsegmented antenna 2; *l*, telson and uropods, inner post lateral spines of telson broadening proximally.

TABLE 4  
COUNTS AND MEASUREMENTS OF STAGE I FURCILIAS OF *Nyctiphanes australis*

NUMBER OF PLEOPODS	TELSAL SPINES	NUMBER OF SPECIMENS	RANGE OF LENGTH, MM.	AVERAGE LENGTH, MM.
1.....	7	1	2.5	....
2.....	7	2	2.5	....
3.....	7	13	2.5 to 2.8	2.7
4.....	7	33	2.7 to 3.0	2.8

TABLE 5  
COUNTS AND MEASUREMENTS OF STAGE II FURCILIAS OF *Nyctiphanes australis*

NUMBER OF SETOSE(S) AND NON-SETOSE(N) PLEOPODS	TELSAL SPINES	NUMBER OF SPECIMENS	INSTAR GROUP	LENGTH RANGE, MM.	AVERAGE LENGTH, MM.
1S 3N.....	7	1	....	3.1	....
3S 2N.....	7	20	....	3.1 to 3.8	3.6
4S.....	7	1	....	3.6	....
4S 1N.....	7	{ 23	1	3.4 to 3.8	3.6
		{ 17	2	3.4 to 3.6	3.5
5S.....	7	{ 24	A	3.6 to 4.2	3.9
		{ 23	A'	4.0 to 4.7	4.3

limb development are in the first group. In the second, two of three instars are listed (Figs. 17*g, h*, instar A; 17*i-l*, instar A'); these belong in Furcilia II as in neither is the endopod of antenna 2 segmented (Fig. 17*k*), but the third instar has the segmented endopod and is listed in Furcilia III.

Throughout all instars, the frontal plate remains broad-based, more or less squarely truncate and covers a considerable portion of eye and stalk (Fig. 17*j*). The laterodistal spine on segment 1 of antenna 1 persists, reaching from two-thirds to almost the outer end of segment 3 of the peduncle; the flagellae are initially about twice the length of those in the last instar of Furcilia I, but are elongate and slender by the final instar of Furcilia II (Fig. 17*j*). A pair of dorsolateral tergal wings appear on the first abdominal segment in the first instar (Fig. 17*e*) and persist throughout the instars of this and Furcilia III. The telson (Fig. 17*b, l*) remains twice as long as the sixth abdominal segment; the ratio of length, to the width at the distal extremity, changes from 3:1 to 4:1 and that of length of telson

to the length from its base to the lateral spines changes from 5:3 to 4:3, by the end of the series. The inner uropods reach about two-thirds the way to the lateral spines in the first, and all of the way in the final, instar.

Of the thoracic limbs (Fig. 17) the endopod of limb 1 commences to elongate relative to the exopod at the instar with 4 setose pleopods. At that with 1 setose and 3 non-setose pleopods limb 2 is 3-segmented, with 2 terminal setae and clearly defined buds of gill and exopodite; by the 4 setose pleopod stage the tarsal segment is 3-jointed (i.e., with 3 subsegments) and the limb is moderately setose, has a 2-branched gill and a stout exopodite. Limb 3 progresses from an elongate rudiment to a 3-segmented, stout appendage, with 2 terminal setae, a single gill and a small, stump-like exopodite. Limb 4 becomes an elongate kneed rudiment.

The instars comprising the instar-groups with 7 telsal spines and either 4 setose and 1 non-setose or 5 setose pleopods (Fig. 17) are differentiated by the degree of development reached by the thoracic limbs; relevant data



TABLE 6  
COMPARISON OF LIMB DEVELOPMENT AMONG INSTARS OF THE INSTAR-GROUPS POSSESSING 7 TERMINAL SPINES ON THE TELSON AND EITHER 4 SETOSE  
AND 1 NON-SETOSE OR 5 SETOSE PAIRS OF PLEOPODS IN *Nyctiphanes australis*

LIMB NUMBER	CHARACTER	FURCILLA II				FURCILLA III	
		With 4 Setose and 1 Non-setose Pleopods		With 5 Setose Pleopods		With 5 Setose Pleopods	
		Instar 1	Instar 2	Instar A	Instar A'	Instar B	
2	Segments, general	Complete, 3 tarsal joints	Complete	Complete	Fully developed	Fully developed limb	
	Setae	Sparse, overall	Moderate	Moderate	.....	Setose	
	Exopod	Well developed bud, no setae	2-terminal setae	2-terminal setae	.....		
	Gill	2-branched	2-branched	2-branched	.....		
3	Segments, general	3-segmented; tarsal joints indistinct	Tarsus 3-jointed	Tarsus 3-jointed	Fully developed	Fully developed, and almost as long as limb 2	
	Setae	2, terminal	Moderate, overall	Moderate-strong, overall	Strongly setose	.....	
	Exopod	Well developed bud	Non-setose	Non-setose	Terminal setae	.....	
	Gill	2-branched	2-branched	2-branched	.....	.....	
4	Segments, general	Kneed, indistinct 2 segments	Stout, 3-segmented	3-segmented	Tarsus 3-jointed	Fully segmented, well developed; about half as long as 2	
	Setae	.....	Terminal	Terminal	Moderate, overall	Moderate-strong	
	Exopod	Rudiment	Large bud	Large (elongate) bud	Non-setose	With single terminal seta	
	Gill	Well developed bud	2-branched	2-branched	2-branched	.....	
5	Segments, general	Elongate bud	Elongating, kneed rudiment	Elongate, kneed rudiment	2-3 segmented	3-segmented	
	Setae	.....	.....	.....	2, terminal	Sparse on terminal seg- ment	
	Exopod	Bud	Large bud	Large bud	Elongate bud	Elongate, rudimentary	
	Gill	Bud	2-branched	2-branched	2-branched	2-branched	
6	Segments, general	Bud	Elongating rudiment	Elongate rudiment	Unsegmented, kneed rudiment	Elongate, kneed rudi- ment	
	Setae	.....	.....	.....	.....	Non-setose	
	Exopod	.....	Bud	Elongate bud	.....	.....	
	Gill	.....	Bud	Bud	Single	2-branched	
7	General	Bud	Bud	Bud	Bud, increasing in length	Elongate bud; 2- branched gill	

are summarised in Table 6 (see also Table 9).

It is seen that the degree of differentiation in instar 2 and instar A (Fig. 17*g, h*) is similar. This is possibly due to the same number of ecdyses having been passed in the development paths of these two (different) instars. Contrarily, several degrees of development in each of the two instar-groups suggest that additional ecdyses are necessary during the course of development of some specimens, to attain this end.

FURCILIA, STAGE III: (Fig. 18).

Table 7 presents data on the "Lachlan" specimens of this stage.

The tergal wings (Fig. 18*a, g*) on the first abdominal segment persist throughout the series of instars. The frontal plate of the carapace gradually narrows at the base, but is still comparatively broad; the front margin becomes broadly rounded in the later instars. The uropods elongate and become slender and reach a little beyond the lateral spines. The telsal length to width (at the tip) attains the ratio of 6:1; by the last instar the outer post-lateral spines are much reduced, the middle pair are slender and beginning to reduce and the inner are long and broad; the telson is round ended with a short, acute spine.

The squame (Fig. 18*f, h*) is strongly setose on its inner margin and develops a disto-

lateral spine. The flagellae of antennae 1 and 2 increase in length until they are about three times the length of the peduncles. The distolateral spine of segment 1 of antenna 1 persists. At the stage of instar E, a wing-like expansion begins to develop dorsolaterally on the distal end of segment 1, antenna 1; this has increased in size by instar F, and from instar K onwards is a conspicuous, triangular lappet.

As in Furcilia II the individual instars of the instar-groups are identifiable by the state of differentiation of the limbs; and again there is duplication in the degree of limb development between one or more instars of one group and some of the following (except that no overlap was apparent between the groups with 5 and 3 telsal spines).

The stage of development of limbs 5, 6 (Fig. 18*d, e*), and 7 are of chief concern for identifying the instars of each group, and data are tabulated in Table 8 for those instar-groups with 5, 3 and 1 telsal spines.

The interrelationships between instars of one group and those of another are illustrated in Table 9. In this, those instars of one group which show identical limb development with those in another are linked by dashed lines; as well, an instar arising directly from a previous one is connected to it by a solid line. It is apparent that relationships are complex,

TABLE 7  
COUNTS AND MEASUREMENTS OF STAGE III FURCILIAS OF *Nyctiphanes australis*

NUMBER OF SETOSE PLEOPODS	NUMBER OF TELSAL SPINES	NUMBER OF SPECIMENS	INSTAR	LENGTH RANGE, MM.	AVERAGE LENGTH, MM.
5.....	7	17	B	4.3 to 4.8	4.5
5.....	6	2	....	.....	....
		{ 13	C	4.4 to 5.0	4.6
5.....	5	{ 13	D	4.4 to 4.6	4.6
		{ 14	E	4.3 to 5.2	4.9
5.....	4	2	....	.....	....
5.....	3	{ 13	F	4.9	4.9
		{ 14	G	5.0 to 5.7	5.2
5.....	2	6	....	.....	....
		{ 13	H	4.4 to 5.0	4.8
5.....	1	{ 14	J	5.3 to 5.7	5.4
		{ 14	K	5.4 to 6.5	5.9



TABLE 8  
LIMB DIFFERENTIATION OF INDIVIDUAL INSTARS OF FURCILLA III, *Nyctiphanes australis*

INSTAR	NUMBER OF TELSAL SPINES	THORACIC LIMB			OTHER CHARACTERS
		5	6	7	
B.....	7	See instar B, Table 6			
C.....	5	Limb development as for instar B, Table 6			
D.....	5	Stout, sparsely setose; tarsus 3-jointed; exp. non-setose; 3-branched gill	Kneed, 2-3 segments, non-setose. No exp.; 2-branched gill	Bud; 2-branched gill	
E.....	5	Fully developed; $\frac{2}{3}$ length of limb 4; exp. non-setose	Tarsus 3-jointed; limb sparsely setose; small bud-like exp. occasionally; 2-branched gill	Elongate, kneed rudiment; 2-branched gill	Wing-like extension dorso-laterally on distal end seg. 1 of antenna 1
*F.....	3	Exopodite with terminal seta	Limb 3-segmented, sparsely setose; 2-branched gill	Elongate bud; 2-branched gill	Extension on seg. 1, ant. 1, more advanced than E; stout, forwardly curving protrusion
†G.....	3	Exopodite with terminal setae	Tarsus 3-jointed; limb moderately setose; 3-branched gill	2-segmented, single terminal seta; 2-3-branched gill	Extension on seg. 1, ant. 1, becomes a triangular, forwardly curving flap-like protrusion
*H.....	1	Twice length of limb 6; exopodite with terminal seta	3-segmented, sparsely setose, 2-branched gill	Elongate bud; gill 2-branched	Ant. 1, segment 1 as for instar F
†J.....	1		Tarsus 3-jointed; limb moderately setose; 3-branched gill; (exp. in young males)	2-segmented with or without setae; 2-3-branched gill	Ant. 1 segment 1 as for instar G
K.....	1		Fully developed, strongly setose; no exp., or exp. with terminal setae (males)	Moderately setose, half length of limb 6; no exopodite	Extension on seg. 1, ant. 1, now a conspicuous lappet

\*Denotes identity in limb development between instars F and H.  
†Denotes identity in limb development between instars G and J.

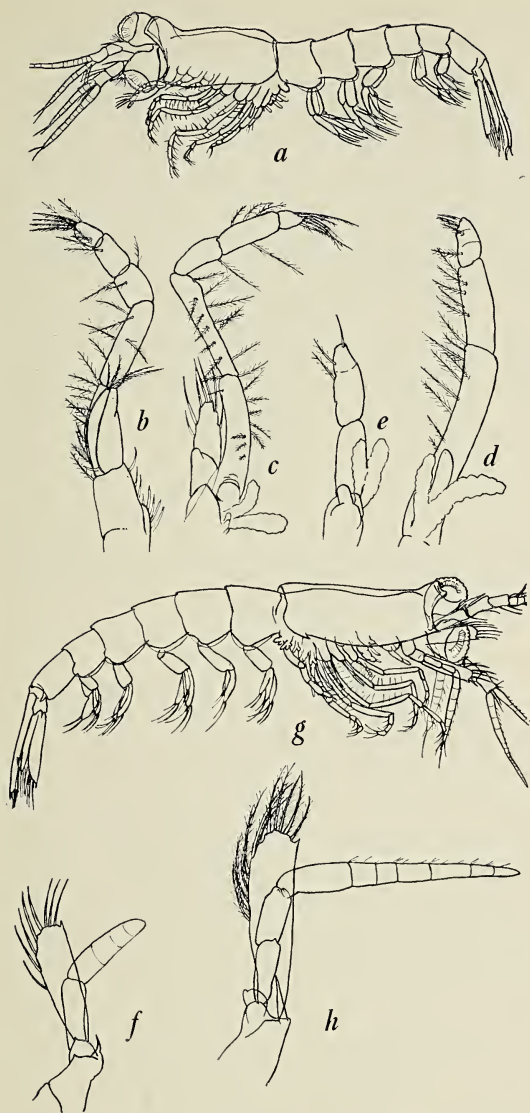


FIG. 18. Two instars of Furcilia Stage III of *Nyctiphanes australis* G. O. Sars. *a-f*, Instar D, from the instar-group with 5 telsonal spines: *a*, Dorsolateral aspect of 4.5 mm. specimen; *b*, *c*, *d*, *e*, thoracic limbs 1, 2, 5, 6; *f*, antenna 2. *g*, *h*, Instar F, from the instar-group with 3 telsonal spines: *g*, lateral aspect of 4.9 mm. specimen; *h*, antenna 2.

but that the table illustrates only a portion of the picture. For example there is no indication of the origin of either instars B or E, or of the fates of instars A or C. Much more material than was available to me is necessary

to complete the developmental paths indicated by the table. Sheard's (1953) diagrams again demonstrate possible paths.

It seems probable that the instar-groups, with their instars having differing degrees of limb development, must arise from specimens undergoing additional ecdyses in Furcilia I or early in Furcilia II. It is perhaps noteworthy that the first indication of an instar-group is among specimens with 4 setose and 1 non-setose pleopods at a later stage of Furcilia II. It is probable that developmental paths following different courses (i.e., paths involving different combinations of setose and non-setose pleopods) first come together in this late stage of Furcilia II. Thenceforth specimens of the several instars would develop along parallel lines until maturity is reached.

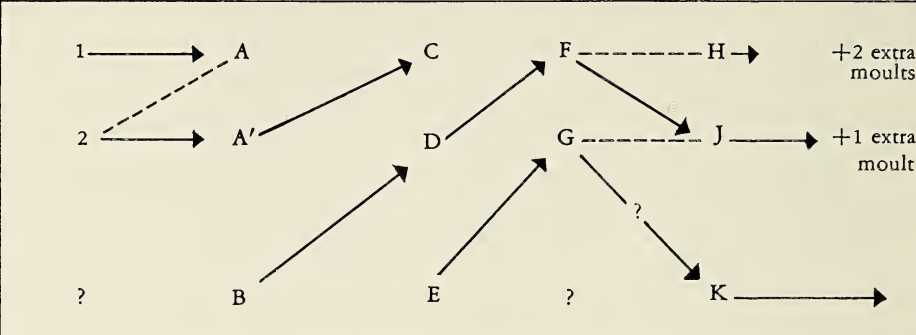
#### *Development of Thysanoessa gregaria*

Gurney (1947) described the development of *Th. gregaria* from the first furcilia to the fifth cyrtopia from material collected around Bermuda. The first three of Gurney's five furciliae were obtained in the New Zealand material. A detailed comparison of these with the descriptions of those from Bermuda reveals only slight differences in the proportion of length to breadth of the telson and in the lengths of the second to fourth lateral spines (the post-laterals) on the telson. In Furcilia I, Gurney states the telson is three times as long as wide, and "spine 4 not generally longer than spine 3, and rarely as long as the telson is wide"; in the New Zealand specimens the telson may be 3.5 times as long as wide and the spines are longer than the width of the telson. In other characters such as the form and extent of the rostral plate, number and position of spines on the telson, degree of limb development, proportional lengths of segments of antenna 1, and in the pleopod development, there are no discernible differences.

According to Gurney, *Thysanoessa gregaria* differs from the other species of the genus in



TABLE 9  
RELATIONSHIPS OF INSTARS IN THE 'INSTAR-GROUPS' OF FURCILIA STAGES II AND III, *Nyctiphanes australis*  
(Explanation in Text)

FURCILIA CHARACTERS	FURCILIA STAGES AND CHARACTERS							
	II 4S 1N		II and III 5S 7Sp		III 5Sp	III 3Sp	III 1Sp	Post Larval*
Instars								

\* Post larval stage: the number of extra moults that are considered necessary for specimens to undergo in order to reach a stage of development comparable with those of instar K (the most advanced) are indicated.  
Abbreviations of characters: S—setose pleopods; N—non-setose pleopods; Sp—terminal telal spines.

having the rostral plate pointed from Furcilia Stage I and in the reduction in number of telal spines during Stage IV. Appropriate furcilia stages were not available from the local collections to check the latter character, but the form of the rostral plate was similar in the earlier stages.

There was no morphological variation among the specimens examined.

Einarsson (1945) has summarised previous expressions of opinion on and added considerably more evidence towards the view that neritic euphausiid species show much greater variation in the morphological features of the larval instars than do oceanic species. The large range of instars so far demonstrated for the typically neritic species of *Nyctiphanes* (Sheard, 1953; Boden, 1951, 1955; and others) concurs in this, as do the small numbers of well-defined (dominant) instars for the southern and oceanic *Euphausia* species ( John, 1936; Fraser, 1936). However, Sheard maintains that dominant instars do not necessarily obtain in either neritic species, e.g., *N. australis*, where there may be numerous instars, or in

oceanic species, e.g., *Euphausia simplex*, where there are fewer instars. He regards the so-called dominant instars of *N. australis* as being significant only in local stocks, with the distinguishing characteristics of such dominants varying from place to place as environmental conditions change. By studying collections covering the ecological range of the species these locally occurring 'dominants' become submerged in a life-history series which in overall view is characterised by a diffuse variety of instars. Boden (1955) questions this viewpoint of indeterminate dominants.

The "Lachlan" collections of *N. australis* are small. Nevertheless, a variety of the instars which may occur were available. In that the material is from a restricted environmental range and, therefore, is essentially a local stock, the apparent dominant instars in Furcilia I, II, and III could conform to Sheard's view of the local origin of such dominants. The New Zealand material exhibits the additional complexity of the 'instar-group' wherein characters, which have been regarded as signifying a particular instar, are found to

include what appears to be a number of instars; these are separable on the several degrees of differentiation reached by the thoracic appendages. The orderliness, and interrelationships between the instars of these instar-groups (Table 9), seem to preclude the possibility that the instars are composed of specimens in which morphological variations have arisen due to changes in such environmental factors as temperature.

The larval development of two oceanic species, *Euphausia lucens* and *Thysanoessa gregaria*, presents an opposing view to that expressed by Sheard (1953) from his studies of *N. australis* and *E. simplex*. In *E. lucens* morphological variants were recorded only as rare exceptions in an orderly series of closely diagnosed instars; nor were there any indications of the instar-groups of *N. australis*. There were no variants in the material for *T. gregaria*. Dominant stages were undoubtedly present in both (see Table 10 for *E. lucens*). This may have been due to inadequate sampling (Sheard, 1953); nevertheless, there is general conformity in the larval histories of a number of oceanic species, in that there are small numbers of well defined instars. This suggests that those instars deviating from the usual expression of an oceanic species' life history may be regarded as exceptional to the dominant instars.

DIURNAL VARIATION IN NUMBERS OF  
EUPHAUSIIDS AT THE SURFACE

Little information on the diurnal movements of southern euphausiids is available.

Tattersall (1924) reported of "Terra Nova" samples that numbers taken at night were much greater; he also (1936a) described the vertical distribution during daylight of one species at two stations near the Great Barrier Reef. Hardy and Gunther (1935) discuss and illustrate vertical movements for various developmental stages of *Euphausia superba* and for *E. frigida*, *E. triacantha*, *E. vallentini*, and species of *Thysanoessa* from South Georgia. For the Northern Hemisphere, Esterly (1914b) discusses vertical distribution and movements of euphausiids in the Californian area; Leavitt (1935, 1938) extensively discusses vertical distribution of species, and Moore (1949, 1950) illustrates vertical distribution and migration for the Bermuda area.

Vertical distribution cannot be demonstrated for the present collections since no vertical hauls were taken. The fact of diurnal migration is apparent, however, through the diurnal variation of numbers taken in surface tows, both in the station series 74 to 85 in western Foveaux Strait, and the curves constructed for all other surface tows. In Figure 7 the catch per tow for *Euphausia lucens*, *Nyctiphanes australis*, and *Thysanoessa gregaria* is expressed as a percentage of the whole catch of each species for stations 74 to 85 (see also for mysids, the curves for two species of which are included). Both *E. lucens* and *T. gregaria* arrive at the surface in large numbers at 2300 hours, an hour before *N. australis*, and more or less maintain these numbers until 2400 hours when they, together with *N. australis* disperse, leaving many fewer specimens

TABLE 10  
DOMINANCE IN FURCILIA STAGES OF *Euphausia lucens*

PLEOPOD DEVELOPMENT	TELSAL SPINES	ANTENNA 2, ENDOPODITE	NUMBER OF SPECIMENS	AVERAGE LENGTH, MM.	FURCILIA STAGE
4 non-setose . . . . .	7	Unsegmented	43	3.0	I
4 setose, 1 non-setose .	7	Unsegmented	70	3.8	II
5 setose . . . . .	5	Unsegmented	44	4.7	III
5 setose . . . . .	6	Unsegmented	2	....	III
5 setose . . . . .	5	Segmented	16	5.2	IV
5 setose . . . . .	3	Segmented	17	5.4	V
5 setose . . . . .	1	Segmented	16	5.6	VI
5 setose . . . . .	2	Segmented	2	....	VI



to be taken in the tow at 0100 hours. At 0200 hours, and accompanying a similar rise for mysids, there is a sharp increase in numbers of *N. australis* and *T. gregaria*, but for *E. lucens* there is only a check to the rate of decrease of numbers being taken. As was discussed for the mysids, the factors contributing towards this second rise (at 0200 hours) are not understood. Nevertheless, there are similarities between this curve and that obtained for all other stations (Fig. 19). The main rise commences at 2100 hours and reaches a peak at 2300 hours in both; an absence of specimens at 2400 hours (in Fig. 19) probably corresponds with the 0100 hours decrease in collections from stations 74 to 85. This is succeeded by a rapid increase over the next hour to 0100 hours, an hour earlier than for stations 74 to 85, when again there is a fairly rapid decrease, then a check at 0300 hours (corresponding to the pre-dawn rise?) and the final dispersion due to the dawn descent. A catch of 732 specimens at station 308 at 0500 hours (indicated in Fig. 19 by the dashed line) falls outside the normal pattern and may be the result of sampling a swarm which has persisted through to daylight.

#### SUMMARY

Collections were made from the survey frigate, H.M.N.Z.S. "Lachlan," between Wellington and the southern extremity of South Island during January, February, and March, 1951, and between southern New Zealand and Auckland and Campbell islands in November, 1951. In all, 86 stations representative of this coverage have been examined and the mysid and euphausiid fauna reported on.

Two species of mysid, *Tenagomysis macropsis* and *T. tenuipes* were collected about Foveaux Strait; this extends the range of *T. tenuipes* 200 miles northward from Auckland Islands. The collections of *T. macropsis* slightly extend the area from which it has been taken previously. *T. tenuipes* was originally described from a single male from the Auckland Islands; the present material has afforded the opportunity

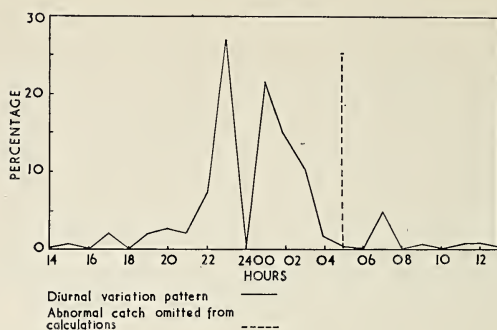


FIG. 19. Diurnal variation in surface waters for all species of euphausiid for the period January through March, 1951. The catch for each hour is expressed as a percentage of the total of all specimens captured.

of reporting on and adding to the systematic morphology of males and females. For both species the larval development, which is continuous, has been described.

Five species of euphausiid were taken; four, namely *Euphausia lucens*, *E. vallentini*, *Thysanoessa gregaria*, and *Nyctiphanes australis* had been recorded previously, but one, *Nematoscelis megalops* (?) is a new record for the southern Pacific.

The larval development stages of *Euphausia lucens* have been described. From a comparison of these with early stages described as *E. lucens* from South Africa, the writer concludes that the latter account is of another species. Instars of the three furcilia stages of *Nyctiphanes australis* are described. It has been found that some of the 'instars,' previously designated by certain morphological characters, in reality appear to be groups of instars in which the individual instars are identifiable by the degree of differentiation reached in the thoracic appendages. The first three stages obtained for *Thysanoessa gregaria* show that its development in New Zealand waters closely parallels that of Bermudan material.

Data are presented on the distribution of both the mysids and euphausiids about New Zealand.

The diurnal variation of numbers at the surface indicates that a vertical migration oc-

curs for mysids and euphausiids which follows the pattern for other zooplanktonic organisms. Differential migration between adults and larval *Tenagomysis macropsis* has been recorded.

This investigation was carried out as a part of a wider survey of southern New Zealand zooplankton during my service in the New Zealand Defence Scientific Corps, attached to the Royal New Zealand Navy. Laboratory facilities were provided at Victoria University College by Professor L. R. Richardson, head of the Department of Zoology for which, and for whose supervision of this study, I am most grateful. I am also most appreciative of the service extended by Dominion Chemical Laboratory for making salinity determinations, and to Mr. W. H. Dawbin for reading the proofs of this paper.

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# Three New Copepods from Brackish-Water Lakes of Japan

TAKASHI ITO<sup>1</sup>

THE PRESENT PAPER deals with three new copepods found in brackish-water lakes of Japan. Two of them were obtained from the brackish fish-culture ponds along the western coast of Ise Bay, Mie Prefecture. The third specimen was sent by Professor Kikuya Mashiko of Kanazawa University and was collected from a small brackish-water lake in Hegura Island, one of the isolated islands in the Sea of Japan.

I wish to acknowledge my indebtedness to Professor Yaichiro Okada who kindly afforded me the facilities for studying the specimens which I have described in the present paper; to Dr. Masuzo Ueno, Otsu Hydrobiological Station of Kyoto University for his valuable advice; and to Professor Kikuya Mashiko of Kanazawa University who sent me the material of *Halicyclops japonicus*.

## *Acartia iseana* n. sp.

Fig. 1

FEMALE: Length 0.955 mm., not including furcal setae.

Head distinctly separated from first thoracic segment. Rostral filaments present (Fig. 1c). Fourth thoracic segment completely fused with fifth. Lateral angle of last thoracic segment rounded, furnished with 4 spinules on either side. Genital segment not laterally dilated, about as long as other two abdominal segments combined, second segment about twice as long as anal segment. First two abdominal segments each with 6 spinules along distal margin of dorsal surface.

Furcal rami about 2 times as long as wide; inner margin with a few hairs. First antenna

of 17 segments, when reflexed scarcely reaching end of anterior division of body.

Legs 1-4 with formula 3,2/3,2/3,2/3,2. Leg 5 with basal segment longer than wide; outer seta relatively short, shorter than terminal spine. Exopodite unsegmented, in form of a stout spine with rounded protuberance on ventral side of base; terminal spine nearly straight, about 3 times as long as basal segment, armed distally with stout spinules on either side. (Fig. 1h, i.)

MALE: Length 0.880 mm. Abdomen relatively longer than in female, and consisting of 5 segments, segment 4 well defined, but small. Furcal rami shorter than in female, 1.3 times as long as wide.

Leg 5: Right leg; basal segment longer than wide (about 2:1); lengths of basal segment and exopodites 1 and 2, 27:35:30 ( $\mu$ ); inner margin of exopodite 1 smooth, but with row of fine hairs; inner lobe of exopodite 2 very prominent, longer than wide, bifurcate at top; exopodite 3 very narrow at base, curved, without spine on outer margin, but with a spine on inner edge. Left leg; lengths of segments, 35:30:41 ( $\mu$ ); exopodite 2 elongate, more than 4 times as long as wide, bearing a small spine on top, with a few hairs on inner margin distally. (Fig. 1j.)

LOCALITY: Brackish-water fish ponds on coastal regions of Tsu and Matsusaka Cities, Mie Prefecture, middle Japan.

HOLOTYPE: Female, and allotype male. Taken from a mullet pond in Yonezu, Tsu City, Mie Prefecture. The type is deposited in the Faculty of Fisheries Collection, Prefectural University of Mie.

VARIATION IN BODY LENGTH: Female 0.856-1.054 mm., male 0.868-0.905 mm.

REMARKS: I found this species in six brack-

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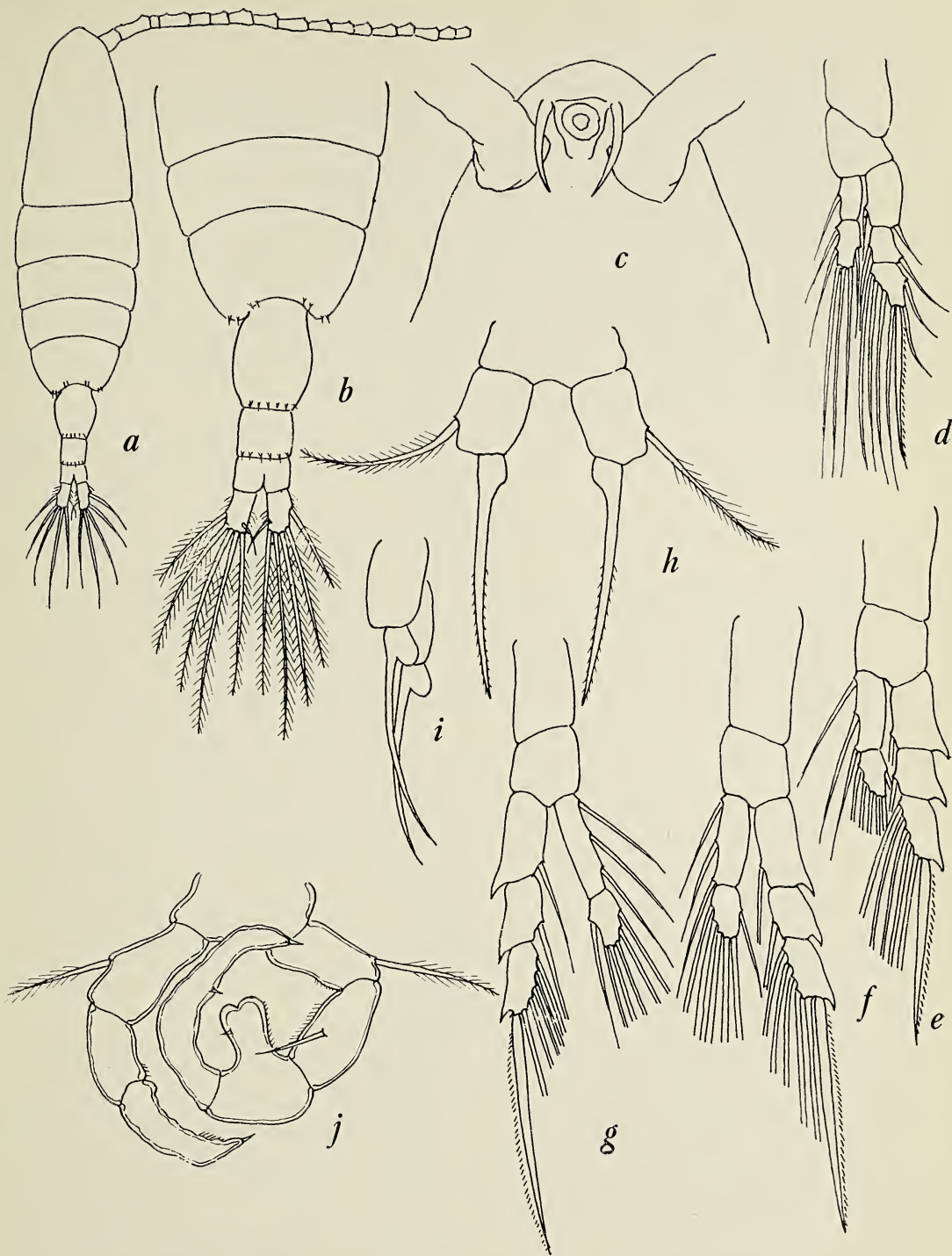


FIG. 1. *Acartia iseana* n. sp.: *a*, Dorsal aspect of female; *b*, abdomen and furca (dorsal); *c*, rostrum; *d*–*g*, legs 1–4; *b*, *i*, leg 5 of female, dorsal and lateral; *j*, leg 5 of male.



ish-water ponds on the coast regions of Yonezu, Tsu City, of Karasu-machi and of Matsusaka City, Mie Prefecture. Usually, this species is in company with other brackish-water forms, *Sinocalanus tenellus* (Kikuchi), *Pseudodiaptomus inopinus* Burckhardt, and *Brachionus plicatilis* O. F. Müller. The chlorinity of the ponds in which the species is distributed, ranges from 5.560 to 12.928 parts per thousand.

*Acartia iseana* is allied to a marine form, *Acartia biflosa* Giesbrecht, but it is distinguishable from *biflosa* by the absence of the fine hairs on the dorsal surface of the abdomen and by the structures of leg 5 of both sexes.

*Acartia tsuensis* n. sp.

Fig. 2

FEMALE: Length 0.943 mm., not including furcal setae.

Head separated from first thoracic segment. Rostral filaments present, more slender than in *A. iseana*. Last two thoracic segments fused. Lateral angle of last thoracic segment rounded, with 6 spinules on either side. Genital segment scarcely longer than other two abdominal segments combined. First two abdominal segments each with 6 spinules along distal margins of dorsal surface. Furcal rami rather shorter than that of the former species, 1.5 times as long as wide.

First antenna of 17 segments, when reflexed extending beyond end of anterior division of body and reaching to middle portion of genital segment.

Legs 1-4 with formula 3,2/3,2/3,2/3,2. Leg 5 with basal segment longer than wide, outer seta rather slender and long. Exopodite unsegmented, proximal portion wider than distal spine, about 2 times as long as wide, bearing well-developed, pointed process on outer edge; terminal spine curved inwards midway, without spinules on either side. (Fig. 2*b*.)

MALE: Length 0.843 mm. Leg 5: Right leg; basal segment longer than wide (about 2:1); lengths of basal segment and exopodite 1 and

2, 39:42:39 ( $\mu$ ); inner margin of exopodite 1 smooth; inner lobe of exopodite 2 very prominent, about as long as wide, its top not bifurcate; exopodite 3 very narrow at base, curved, without spines on outer margin, but with a spine on inner edge as in *A. iseana*. Left leg; lengths of basal segment and exopodite 1 and 2, 46:31:26 ( $\mu$ ); basal segment rather slender, about 2 times as long as wide; exopodite 1 very simple and smooth; exopodite 2 consisting of 2 portions, proximal protuberance bearing a slender spine on inner margin and narrower distal portion with small spine on top and subapical small process. (Fig. 2*i*.)

LOCALITY: Twelve brackish-water fish ponds in which the mullet, *Mugil cephalus* L. is cultured, on coasts of Kumozu, Tsukaigan, and Heta regions in Tsu City, Mie Prefecture, middle Japan.

HOLOTYPE: Female, and allotype male. Taken from a brackish-water fish pond in Heta of Tsu City, Mie Prefecture. The type is preserved in the Faculty of Fisheries Collection, Prefectural University of Mie.

VARIATION IN BODY LENGTH: Female 0.893-0.992 mm., male 0.818-0.868 mm.

REMARKS: This species is found in company with other brackish-water plankton animals, *Sinocalanus tenellus* (Kikuchi), *Pseudodiaptomus inopinus* Burckhardt, *Neomysis japonica* (Nakazawa), and *Brachionus plicatilis* O. F. Müller in most cases, but not accompanied by *Acartia iseana*. The chlorinity of these ponds ranges from 6.696 to 7.768 parts per thousand.

*A. tsuensis* is allied to *A. iseana* but it is distinguishable from the latter as follows:

Furcal rami 2 times as long as wide; exopodite of leg 5 in female bearing a rounded lobe at base of terminal spine; inner prominence of exopodite 2 of right leg 5 in male bifurcate. . . . .	<i>Acartia iseana</i>
Furcal rami 1.5 times as long as wide; exopodite of leg 5 in female with a pointed process; inner prominence of right leg 5 in male rounded. . . . .	<i>Acartia tsuensis</i>

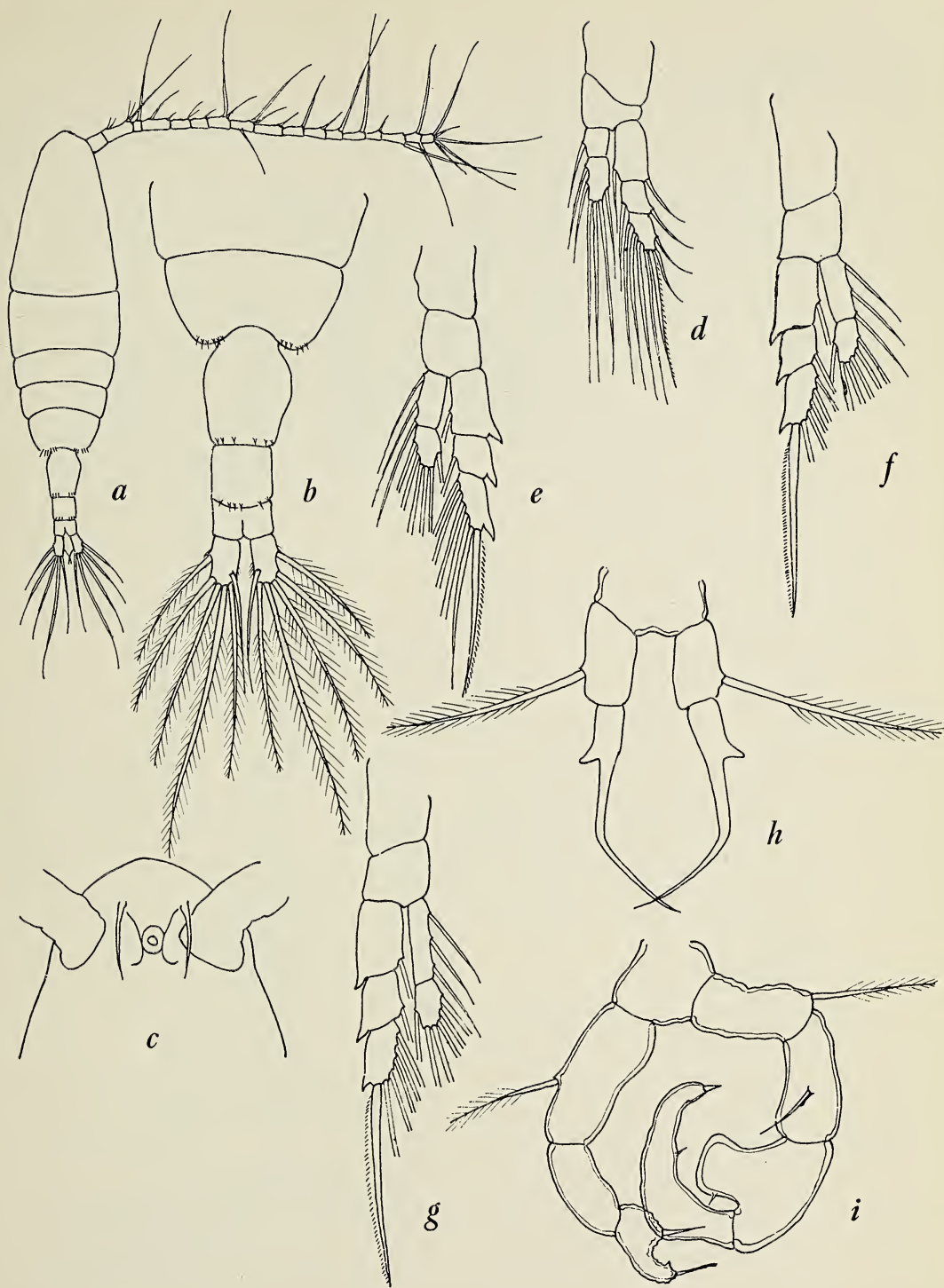


FIG. 2. *Acartia tsuensis* n. sp.: *a*, Dorsal aspect of female; *b*, abdomen and furca (dorsal); *c*, rostrum; *d*-*g*, legs 1-4; *h*, leg 5 of female; *i*, leg 5 of male.



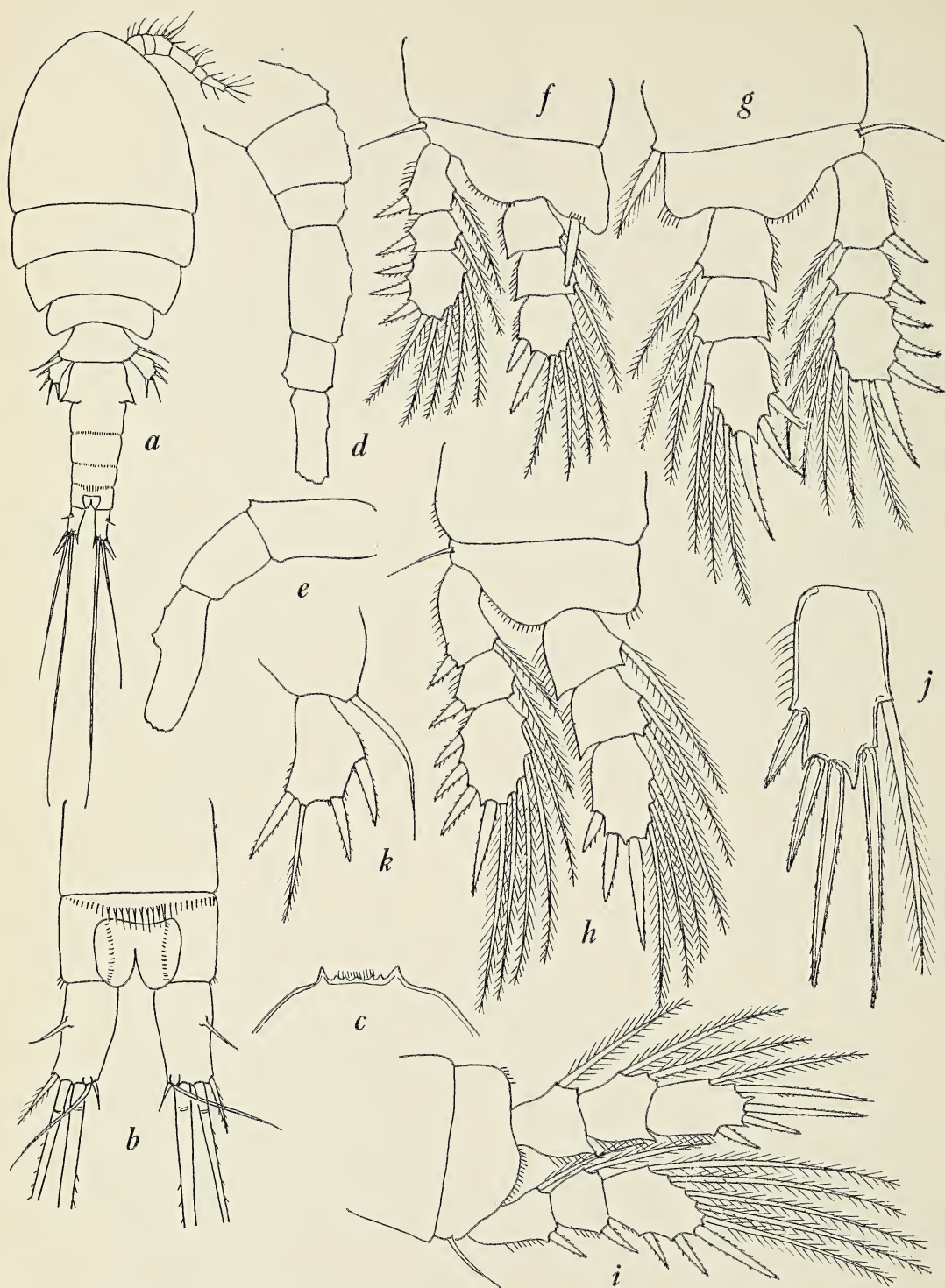


FIG. 3. *Halicyclops japonicus* n. sp.: a, Dorsal aspect of female; b, abdomen and furca (dorsal); c, upper lip; d, e, first and second antennae; f-i, legs 1-4; j, endopodite 3 of leg 4, k, leg 5.

*Halicyclops japonicus* n. sp.

Fig. 3

FEMALE: Length 0.66 mm., not including furcal setae. Body somewhat flattened, with distinct nauplius eye.

Upper lip rather narrow, with about 7 small, blunt teeth (Fig. 3c). First three abdominal segments bearing a row of spinules along posterior end of dorsal surface, middle spinules of the third segment especially well developed. Genital segment sharply produced towards side at middle on either side (Fig. 3a).

Furcal rami relatively long (38  $\mu$ ), nearly twice as long as wide (1.9:1); lateral seta inserted at about middle of furcal rami, somewhat dorsal in position. Lengths of furcal setae as follows (from inner to outer and dorsal): 13:359:184:23:38 ( $\mu$ ). Inner furcal seta very short and small, 0.6 as long as outer (13:23  $\mu$ ); outer seta shorter than furcal ramus; dorsal seta relatively long, much longer than the outer, arising from small protuberance; inner median seta about twice as long as the outer median seta. (Figs. 3a, b.)

First antenna very short, consisting of 6 segments, reaching to middle of cephalothorax, relative length of each segment as shown in Fig. 3d. Second antenna of 3 segments (Fig. 3e).

Legs 1-4 with formula 3,3/3,3/3,3/3,3; spine-formula in exopodite, 3,4,4,3; seta-formula in exopodite, 5,5,5,5; spine-formula in endopodite, 2,3,3,4; seta-formula in endopodite, 4,3,3,1. (Figs. 3f-j.) Endopodite 2 of leg 1 with an inner seta, of legs 2-4 with 2 inner setae. Leg 4 with endopodite 3 rather slender, about twice as long as wide (1.9:1), terminal spines unequal in length, inner spine 1.8 times as long as outer (45:25  $\mu$ ); outer marginal seta replaced by stout spine, 15  $\mu$  in length; distal inner seta also a long, slender spine, 45  $\mu$  in length; but proximal inner seta of usual form. (Fig. 3i, j.) Connecting plate of leg 4 very simple and smooth, without special appendage.

Leg 5 with segment 1 fused with last thoracic segment, with one slender seta; seg-

ment 2 very narrow at base, rather wide at apex, bearing 3 short spines and one slender seta, each side of distal portion with several denticules. (Fig. 3k.)

MALE: Unknown.

LOCALITY: Ryujin-ike (brackish-water lake) on Hegura Island, Japan Sea.

HOLOTYPE: Female, is deposited in the collection of the Faculty of Fisheries, Prefectural University of Mie.

REMARKS: I found this new species in the plankton material collected by Professor Kikuya Mashiko of the Biological Institute, Kanazawa University, 3-VIII-1948, from a brackish-water lake, Ryujin-ike on Hegurajima, Ishikawa Prefecture. The species was accompanied by another brackish-water copepod, *Paracyclops nana* Smirnov. According to Mashiko (1950), the chlorinity of the water of the lake was 5.730 parts per thousand.

*Halicyclops japonicus* is allied to *Halicyclops thermophilus* Kiefer, which was described by Kiefer (1929, 1936) from a salt spring in Koeripan, Java, and which has also been reported by Lindberg (1952), from a limestone cave in Aven Vatonosititsy, Madagascar. *H. japonicus* is distinguished from *thermophilus* by the more slender furcal rami, by the usually armed proximal inner seta of endopodite 3 of leg 4 and by the more distal location of the lateral seta on the furcal rami.

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## NEWS NOTES

### Change in Editor-in-Chief

Upon the completion of volume 10 of *Pacific Science* L. D. Tuthill relinquishes the position of Editor-in-Chief. O. A. Bushnell assumes the

duties of the position. Hereafter, address correspondence concerning manuscripts to Dr. Bushnell.

### International Abstracts of Biological Sciences

The Council of Biological and Medical Abstracts Ltd. has decided to change the title of their journal *British Abstracts of Medical Sciences* to the above.

This decision results from two major developments. The first is an extension of coverage to a wider range of biological research subjects published in journals throughout the world, and the second is that the International Abstracts of Biological Sciences, with the co-operation of the specialist editors selected by the Institute of Scientific Information of the Academy of Sciences of the U.S.S.R. will include, as from the January 1957 issue, translations of the important Russian papers abstracted in the *Referativny Zhurnal Biologii* (Soviet Biological Abstracts) and *Referativny Zhurnal Biologicheskoi Khimii* (Soviet Abstracts of Biological Chemistry), to be published simultaneously with their appearance in Russian.

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istry, Biophysics, Cytology, Embryology, Endocrinology, Epidemiology, Experimental Biology, Genetics, Haematology, Histochemistry, Histology, Immunology, Microbiology, Nutrition, Odontology, Parasitology, Pathology, Pharmacology, Physical Anthropology, Physiology, Radiation Effects, Toxicology and Viruses.

International Abstracts of Biological Sciences is published for the Council of Biological and Medical Abstracts Ltd. by Pergamon Press, London and New York, on a non profit-making basis.

Since the Russian abstracts will have to be translated, the Council requires translators with knowledge of Anatomy, Animal Behaviour, Biochemistry, Endocrinology, Experimental Biology, Experimental Medicine, Microbiology, Odontology, Pathology, Pharmacology and Physiology, and would welcome offers of help. Terms of payment and other details may be obtained from the Honorary Editor: Dr. C. C. N. VASS, c/o Pergamon Press Ltd., 4 & 5, Fitzroy Square, London, W.1, or 122 East 55th Street, New York 22, N.Y.

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